

TIME CRITICAL TARGETING: PREDICTIVE Vs REACTIONARY METHODS
AN ANALYSIS FOR THE FUTURE

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A THESIS PRESENTED TO THE FACULTY OF
THE SCHOOL OF ADVANCED AIRPOWER STUDIES
FOR COMPLETION OF GRADUATION REQUIREMENTS

SCHOOL OF ADVANCED AIRPOWER STUDIES
AIR UNIVERSITY
MAXWELL AIR FORCE BASE, ALABAMA
JUNE 2002

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 00 JUN 2002		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Time Critical Targeting: Predictive Vs Reactionary Methods An Analysis For The Future				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air University Maxwell Air Force Base, Alabama				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 123	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

DISCLAIMER

The conclusions and opinions expressed in this document are those of the author. They do not reflect the official position of the US Government, Department of Defense, the United States Air Force, or Air University.

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ACKNOWLEDGEMENTS

I would like to acknowledge several people without whose support and help I would never have gotten off the ground with this study. Both Dr. Dave Mets and Major John Terino were instrumental in providing me guidance and much help on penmanship. Their efforts as advisors and readers many times go unnoticed at SAAS, working with many students who all need fast response to make the deadline. Thank you for your time and effort.

Also, Colonel Leonpacker and his staff at the Air Force's Research Laboratory - Munitions Directorate at Eglin AFB, Florida were helpful in providing insight as to how advanced weapons work, their associated problems, and the acquisition process. Gregory Jenkins and Ben Plenge, also at Eglin AFB, must be thanked for conceptualizing the idea of a persistence weapon, and its associated CONOPS.

Lastly, I want to thank my wife, Carole, and our four butterflies for their patience, love, and support during this trying time. They always provided me a reason to take a break, even when I was not ready for one. Their smiles, hugs, and tugs, while sometimes an annoyance, kept this project in perspective. To them this project is dedicated.

ABSTRACT

Recent experiences in Operations Desert Storm and Allied Force have highlighted a significant weakness in the USAF's ability to engage time-critical targets. The weakness stems from air power's inability to quickly employ force and kill an emerging target before it disappears back into hiding. In essence, the USAF's engagement sequence, called the kill chain, is not fast enough to detect, locate, identify, and then engage the target. Experience has shown that the enemy has used this method of emerging, engaging, and then dispersing since the beginning of time, and because it is still effective, the enemy has little reason to change. To help solve this difficulty, this thesis introduces and investigates two different approaches (reactive and preemptive methods) and determines how they might solve the problem in 2010. Evidence suggests that the USAF is attempting to solve the problem by using the reactive approach, which first detects a target (with an ISR platform) and then tasks a loitering strike platform to kill it. While this approach is cost effective from a weapons employment perspective, it is not efficient for weapons delivery aircraft. In addition, the reactive approach has two significant problems: 1) one must possess enough persistent ISR platforms to detect targets deep within enemy territory, and 2) one must devise a weapon that can quickly engage targets before they hide. The study found that while this approach has long-term advantages, it will not likely be ready for implementation until around 2020, ten years too late. Because of this fact, the USAF needs a "gap-filler" that will help solve the problem in the meantime. Analysis shows that the preemptive approach might be a viable option. This approach employs weapons in likely target areas before they

emerge, and because of this reason, requires a robust intelligence network that allows some level of prediction to occur. One weapon, the Low Cost Persistent Area Dominance (LOCPAD) miniature munition, may not only help increase ISR collection (and prediction), but also provide a kill mechanism at a reasonable cost. In the end, evidence suggests that the USAF should pursue persistent area dominance munitions as an answer to the time-critical targeting problem.

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Chapter 1

Introduction

"Thus, it is said, one who knows the enemy and knows himself will not be endangered in a hundred engagements. One who does not know the enemy, but knows himself will sometimes be victorious, sometimes meet with defeat. One who knows neither the enemy nor himself will invariably be defeated in every engagement."

— Sun Tzu
The Art of War

Some 2500 years after it was written, today's war makers continue to realize that knowing the enemy is essential to success in war. Experience has shown, however, that while Sun Tzu's overused dictum is true, it certainly is no panacea. In his book *On War*, Carl von Clausewitz asserted that "the general unreliability of all information presents a special problem in war: all action takes place, so to speak, in a kind of twilight, which, like fog or moonlight, often tends to make things seem grotesque and larger than they really are."¹ He goes on to suggest that because of this uncertainty, the "only situation a commander can know fully is his own."² Compounding this problem is the fact that an enemy reacts and adapts to changing circumstances, so even if one had perfect information, its usefulness expires quickly with time. The solution to the problem is to recognize that while perfect information may be the desired goal, the realistic and essential goal is to have better information relative to that of the enemy.

Because of this fact, the United States (US) has invested substantially in reconnaissance and surveillance platforms that allow military leaders and analysts to

¹ Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, N.J.: Princeton University Press, 1976), 140.

observe the enemy, select targets, and later destroy them through the application of force. In attempting to neutralize this capability, however, the enemy has learned to use a variety of techniques, some of which include hiding, deception, and movement. In fact, this behavior gives birth to the adage, "If seeing a target is tantamount to killing it, then seeing others and staying hidden become [sic] the two reigning requirements of combat."³

While there is nothing new to this adage, recent experiences in Desert Storm and Kosovo have highlighted the need to nullify the enemy's ability to become a chameleon. In Desert Storm, SCUD missile transporters, erectors, and launchers (TELs) constantly eluded Coalition efforts to find them, launching forty missiles into Israel in an effort to "destroy the alliance that President Bush painstakingly had constructed." Even though Gen Charles Horner, Joint Forces Air Component Commander (JFACC), prioritized the destruction of SCUD TELs to a high level, dedicating over 4700 sorties to the effort, post-war intelligence showed no proof that a single SCUD was destroyed.⁴

Later in Kosovo, the problem became evident once again. Gen Wesley Clark, the Joint Forces Commander (JFC) for the operation, said, "Even with the intelligence, surveillance, and reconnaissance provided by the Air Force, it was still impossible to determine what was inside vehicles and buildings and under camouflage nets and bridges. Consequently, these "targets" did not get bombed. High-tech delivery platforms were excellent, but intelligence on many targets was inadequate."⁵ This difficulty was

² Ibid., 84.

³ *1998 Strategic Assessment: Engaging Power for Peace*. National Defense University, n.p., on-line, Internet, 10 January 2002, available from <http://www.ndu.edu/inss/sa98/sa98ch15.html>.

⁴ Perry D. Jamieson, *Lucrative Targets: The U.S. Air Force in the Kuwaiti Theater of Operations* (Washington, D.C.: U.S. Government Printing Office, 2001), 49-50; Kevin L. Fox, "Dynamic Targeting: Are We Ready?" (masters thesis, Air Command and Staff College, April 1999), 41; Michael R. Gordon and General Bernard E. Trainor, *The General's War* (N.Y.: Little, Brown and Company, 1995), 246-247.

⁵ Keith Hutcheson, ed., *Unified Aerospace Power in the New Millenium* (Washington, D.C.: Headquarters, USAF/XPX, 7-8 February 2001), 13.

aggravated because of Kosovo's mountainous terrain, enabling mechanized forces to disperse and hide virtually anywhere.⁶ In addition, even when targets were identified, many times aircraft could not respond fast enough to take advantage of the situation because the targets were located in or behind heavy air defenses, which required air-to-air and suppression of enemy air defense (SEAD) aircraft to accompany the strike aircraft to the target. Unfortunately, some targets were left unscathed because support aircraft were not always available in sufficient numbers.⁷ In the end, Gen Clark stated, "Targeting time against time-urgent critical targets for F-15[E] missions was much longer than it should have been. Some progress was made in this area during the war, but the planning must minimize time to "reflex" aircraft."⁸

A RAND analysis highlights Gen Clark's frustration, making two recommendations for the coercive use of air power in future conflicts. One recommendation suggests that because NATO's attempts to "systematically and progressively" destroy Yugoslav military forces were largely unsuccessful, the US and its allies must improve their capabilities to locate, identify, and rapidly strike enemy mobile targets.⁹ The study emphasized that "sensors, surveillance and reconnaissance platforms, target processing and dynamic control measures, weapon systems, and concepts of operation" must be developed to improve the ability to attack enemy armor and artillery forces when dispersed, hidden, or in urban terrain.¹⁰ Fortunately, the United States Air Force (USAF) is heeding RAND's advice.

⁶ Steven Metz, "Asymmetric Warfare: Strategic Asymmetry," *Military Review*, July/August 2001, n.p., online, Internet, 16 October 2001, available from <http://proquest.umi.com>.

⁷ Fox, 35.

⁸ Hutcheson, 14.

⁹ Stephen T. Hosmer, "Why Milosevic Decided to Settle the Conflict Over Kosovo When He Did," RAND Research Brief (Washington, D.C.: RAND, 2001), n.p.

¹⁰ Ibid., n.p.

In order to overcome and destroy elusive surface targets, a reactive or preemptive method may be used.¹¹ Reactive methods attempt to detect, locate, and identify a target in real-time and then assign an aircraft or weapon to kill it. Since the targets are elusive, however, the faster one can proceed from detecting a target to killing it (oftentimes referred to as the "kill chain"), the greater the chance for success. The USAF is pursuing this reactive approach by adopting a "systems of systems" sensor to shooter architecture that eliminates many of the traditional barriers that slow down the kill chain.¹²

The preemptive method, on the other hand, is enabled by persistence, the ability of an aircraft or munition to loiter over an area for a long time, and when discovering a target, to kill it quickly. Traditionally, this method was not viable for two primary reasons. First, aircraft could not loiter for long periods of time in enemy territory because of their limited fuel capacities.¹³ In addition, such missions promised to be long and dull, hardly an efficient use of aircraft, especially since support aircraft would also be required to suppress the threat. In the end, many aircraft would be needed to conduct even a small operation, all waiting for the enemy to move and, thereby, relinquishing the initiative unto the enemy.

Second, intelligence was not good enough to adequately predict where the enemy would act. Assets loitering over the wrong territory would hardly prove worthwhile, resulting not only in wasted time and fuel, but also in the forfeit of other operations. Today, however, with technological advances being made that enable intelligence to

¹¹ Air Land Sea Application Center (ALSA), AFJPM 10-225, *Targeting: The Joint Targeting Process and Procedures for Targeting Time-Critical Targets*, July 1997, II-2.

¹² Todd Fleming and Chuck Paone, "Air Force Developing New 'Constellation' of Integrated Capabilities," ESC Public Affairs and AC2ISR Center, on-line, Internet, 05 December 2001, available from <http://www.hanscom.af.mil/Hansconian/Articles/05182001-1.htm>.

¹³ Air-to-air refueling would degrade the effort because persistence would be compromised when the aircraft left enemy territory to join with the tanker.

predict the enemy's next move, along with stealthy aircraft, unmanned combat aerial vehicles (UCAVs), loitering unmanned aerial vehicles (UAVs), and miniaturized weapons with automatic target recognition (ATR) algorithms, a preemptive approach may, in fact, be feasible.

This thesis investigates the feasibility of the preemptive method and determines whether or not the USAF should pursue the new paradigm through the purchase of low-cost, miniature, persistent, air-to-ground weapons for use in engaging time-critical targets. To conduct the analysis, a four-step process is used. First, research is conducted to determine which future aircraft, spacecraft, and weapons are most promising for use in the 2010 timeframe. This timeframe was selected because it coincides with the projected completion of the USAF's Transformation Force. According to Maj Gen John L. Barry, the USAF's Director for Strategic Planning, the Transformation Force is a "gap filler" that will provide critical capabilities until the Vision Force, heavily reliant on space assets, is implemented in the 2020 to 2025 timeframe.¹⁴ Further, Gen Robert H. Foglesong, the USAF's Vice Chief of Staff, has said, "This midpoint, the first incremental leap in capability, would see a force that is a more dynamic and precise aerospace force. The Transformation Force would have enhanced combat, airlift, and intelligence, surveillance, and reconnaissance (ISR) fleets, be lighter and more agile, and include a more robust space force."¹⁵ Because of this effort to transform the force into a more effective fighting force, Air Combat Command's (ACC) Global Attack Mission Area Plan (MAP), which addresses USAF future force requirements, has identified both

¹⁴ John T. Correll, "The Vision Force," *Air Force Magazine*, November 2000, n.p., on-line, Internet, 10 October 2001, available from <http://www.afa.org/magazine/magz.html>.

¹⁵ Amy Butler, "The CONOPS With a Difference," *Air Force Magazine*, October 2001, n.p., on-line, Internet, 28 November 2001, available from <http://www.afa.org/magazine/Oct2001/1001conops.html>.

Precision Munitions and Combat/Target ID (identification) as primary focus areas.¹⁶ Included in these areas are the need for a flexible, time-critical architecture that includes rapid identification and continuous, real-time, sensor to shooter links.¹⁷ Since these sources suggest that the USAF wants to correct the time-critical targeting problem by about 2010, it follows that this study should also use a similar timeframe. As a side benefit, using a 2010 target reduces the need for speculation regarding future capabilities, thus keeping the assessment more realistic.

Second, once the most promising aircraft, spacecraft, and weapons are determined, they are categorized for use in either the reactive or preemptive method. For example, while a hypersonic missile would probably be used for reactive targeting, a loitering munition would likely best fit preemptive use. Third, evaluation criteria include, but are not limited to effectiveness, cost, ease of future integration, and adaptability. Because the areas of evaluation are qualitative in nature (except for cost), the study focuses not on whether preemptive systems can destroy ninety percent or only fifty percent of time-critical targets, but rather on whether preemptive systems can enhance current and projected future capabilities, helping to destroy time-critical targets at a reasonable cost. Lastly, based on the findings, a course of action will be recommended for the USAF to pursue.

To answer these questions, many sources were researched to find pertinent evidence. Some of these sources included current and proposed future joint and USAF doctrine, concepts of operations (CONOPS), books on technology and warfighting, periodicals, statements and speeches by senior military and government officials,

¹⁶ Headquarters, Air Combat Command, *Combat Air Forces Global Attack Mission Area Plan - FY2002*, October 2000, 4.

interviews, articles written by established defense institutions, and USAF goals and long-range plans. After reading the source material and cataloging them, the pertinent evidence was organized by topic and evaluated by date and the reliability of source. Primary sources have priority over secondary sources. In addition, when evidence conflicts, the most recent evidence is used. Because technological advancements during the past few years sparked the advent of many new capabilities, most books written before 1998 are not very useful.¹⁸ For this reason, much evidence is taken from Internet sources and current periodicals because they have the most up-to-date information - even if second-hand. To ensure accuracy, however, interviews, e-mail, and telephone calls were made to reputable sources to help confirm questionable evidence.

The thesis presents the evidence in five chapters. Chapter one is the introduction, presenting the argument to the reader. Chapter two reveals pertinent background material describing how the kill chain works, thus providing the reader with a deeper understanding of the problem. Chapter three presents the reactive method, associated equipment, and how it is best used. Chapter four introduces equipment and a CONOPS for using the preemptive method. An evaluation is conducted in chapter five, comparing and contrasting previously introduced systems to arrive at a logical conclusion.

¹⁷ Ibid., 18, 22.

¹⁸ Moore's Law, named after Gordon Moore, Intel's co-founder, asserts that the capability to process data is doubling every 18 months. Most experts expect the law to remain valid for at least two more decades.

Chapter 2

Background

They [the enemy] will hide from detection, shield themselves, attack our weapons, and strive in every possible way to dislocate our fires. They will change the political context, disperse into cities, and dare us to apply our firepower into the midst of noncombatants. They will refuse to be detected, located, tracked, targeted, and assessed.

— Robert R. Leonhard
The Principles of War for the Information Age

This chapter provides the necessary background to understand the complex nature of time-critical targeting. The chapter begins by defining time-critical targets and their behavior, followed by an in-depth analysis of the kill chain. Throughout the analysis, time-critical targeting problems are illuminated and, for clarity, are summarized at the end of the chapter. Solutions to these problems will be the focus of Chapters 3 and 4.

Definitions

According to the Air Land Sea Application Center (ALSA), a time-critical target (TCT) is "a lucrative, fleeting, land, or sea target of such high priority to friendly forces that the JFC or component commander designates it as requiring immediate response."¹⁹ Sometimes these targets are also called flex targets, emerging targets, or time-sensitive targets.²⁰ ALSA separates TCTs into two categories, planned and immediate. Planned TCTs, normally fixed and immobile, will not be addressed in this discussion. On the other hand, immediate TCTs are mobile, require established procedures to seek and

¹⁹ ALSA is responsible for providing tactics, techniques, and procedures (TTP) for the joint military forces; Air Land Sea Application Center (ALSA), AFJPAM 10-225, *Targeting: The Joint Targeting Process and Procedures for Targeting Time-Critical Targets*, July 1997, II-1.

²⁰ Joint Publication 1-02, DOD Dictionary of Military and Associated Terms, 12 April 2001, uses the term time-sensitive targets, 435.

destroy them, and will be the focus of this study.²¹ Immediate targets limit their exposure time on the battlefield by moving quickly and using deception. Some examples are SCUD missile TELs, surface-to-air missiles (SAMs), mobile rocket launchers (MRLs), and mobile command & control (C2) vehicles.²² For the remainder of this thesis, any reference to TCTs automatically implies immediate TCTs.

The Kill Chain

The kill chain is the "tooth-to-tail" process that prescribes the sequence of events needed to find, engage, and destroy targets. Also included in the chain is the requirement for post-strike battle-damage assessment (BDA). For ease of discussion, the process has been segmented into 4 levels: ISR and C2, shooter, weapon, and BDA (see Figure 1).

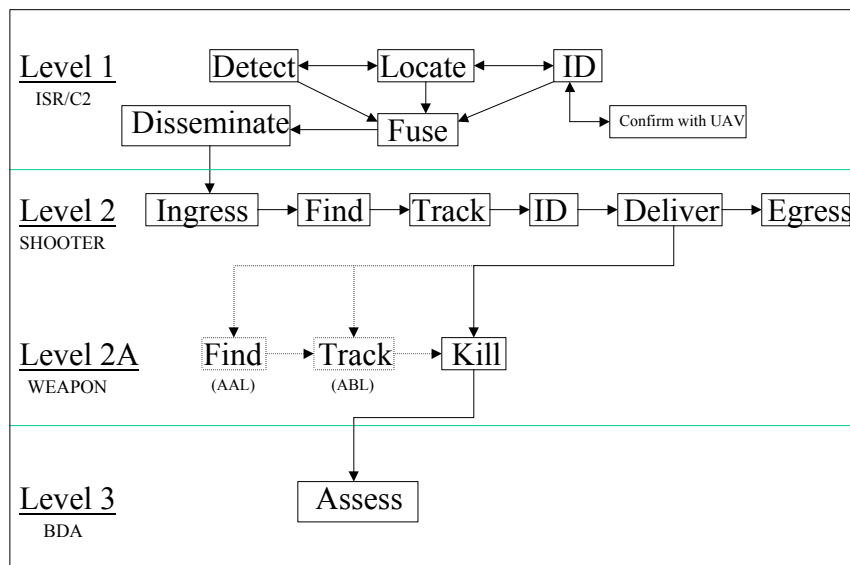


Figure 1 - The Kill Chain

²¹ ALSA, *Targeting: The Joint Targeting Process and Procedures for Targeting Time-Critical Targets*, II-2.

²² Ibid., II-1.

Level 1 - ISR and C2

Level 1, ISR and C2, is the start of the TCT process and begins by using various sensors and techniques to detect, locate, and identify a contact of interest (COI).²³ Because clever adversaries have learned to minimize their signatures and use tactics that can fool certain sensors, and because no one sensor can reliably detect in all environments, many different sensors with different capabilities are needed to obtain a high probability of detection and identification under varied conditions.²⁴ To guide this discussion, sensors are categorized into two types - active and passive.

Active Sensors

Active sensors emit energy and then collect the energy reflected back from an object. By processing and analyzing the returned energy, information about the object is obtained. Radar, a commonly used active sensor, typically uses three techniques to achieve this insight: synthetic aperture radar (SAR), moving target indicator (MTI) and foliage penetrating radar (FolPen).

SAR provides day and night, all weather, long-range surveillance and produces a photograph-like picture of the target area.²⁵ Even with a picture containing a potential contact of interest (COI) however, experience has shown that in most cases full COI identification is not possible because of the picture's poor resolution.²⁶ This fact, along with SAR's limited capability to cover large amounts of territory quickly because of the

²³ William B. Danskine, "The Time Critical Targeting Model," (master's thesis, Air Command and Staff College, April 2000), 14. A COI is a potential target, detected and possibly located, but not yet identified as friendly or hostile.

²⁴ Alan Vick, "Finding Needles in Haystacks," RAND Research Brief (Washington, D.C.: RAND, 1996).

²⁵ Federation of American Scientists, "Joint Surveillance Target Attack Radar System," on-line, n.p., Internet, 28 November 2001, available from <http://www.fas.org/irp/program/collect/jstars.htm>.

²⁶ Danskine, 72.

advanced processing required, results in SAR being most useful for locating (i.e., accurately pinpointing) an object's position.

The second radar technique, MTI, detects vehicular movement. To accomplish this, MTI transmits radar energy and then measures the shift in frequency of the reflected energy returning from an object.²⁷ When a moving object is moving toward or away from the radar, the reflected energy returning is either compressed (a higher frequency) or extended (lower frequency). This shift in frequency is called Doppler effect and is easily measured. The advantage of MTI is that it can cover large amounts of territory in a small amount of time, making it ideal to detect unknown moving objects. MTI is also able to accurately locate a moving vehicle by creating a track on the object.²⁸ Unfortunately, however, MTI has very limited capabilities to identify. In Kosovo, the Joint-STARS could see vehicles moving, but it could not distinguish a tank from a tractor pulling refugees.²⁹ In the end, MTI adds a significant capability to detect and locate moving targets but not much else.

SAR and MTI radars are currently used on the E-8 Joint-STARS, U-2R, RQ-1 Predator UAV, RQ-4A Global Hawk UAV, AC-130U, B-1, B-2, and various tactical fighters.³⁰ Of those listed, however, only the E-8 Joint-STARS, U-2R, and RQ-4A Global Hawk have radars with wide field of views (WFOVs) that can adequately cover large amounts of terrain. One advantage of the E-8 Joint-STARS is its capability to

²⁷ Alan Vick, et al., *Enhancing Air Power's Contribution Against Light Infantry Targets*, (Washington, D.C.: RAND, 1996), 16.

²⁸ Joint Publication 1-02, DOD Dictionary of Military and Associated Terms, 12 April 2001, a track is a record of successive positions of a moving object, 437.

²⁹ Phil M. Haun, "Airpower versus a Fielded Army: A Construct for Air Operations in the Twenty-First Century," *Aerospace Power Journal* XV, no. 4 (Winter 2001): 84.

³⁰ Alan Vick, et al., 16.

process returning radar energy autonomously in real-time.³¹ This allows operators to make faster decisions since the information is presented to them without delay. The U-2R's Advanced Strategic Airborne Radar System (ASARS-2) and the RQ-4A's radar system are near-real-time capable, requiring a ground station to first process the data before sending it to users.³² While the Predator UAV is SAR capable, its narrow field of view (NFOV) sensor and limited sensor range are better used for locating and identifying COIs. This will be discussed in detail later.

The last radar technique, FolPen, uses ultra-wide-band (UWB) radars operating in the high-frequency (HF) and very-high-frequency (VHF) spectrum to penetrate foliage and detect and locate stationary enemy vehicles, equipment, buildings, and even buried objects such as landmines.³³ One limitation of FolPen, however, is that while it can see through foliage, it cannot see through tree trunks. For this reason, FolPen's ability to detect targets in heavily wooded areas is degraded. Since it uses advanced processing similar to SAR, FolPen is best used in detecting and locating targets in isolated areas of heavy foliage where the search area is minimized. Since it is a relatively new technology, FolPen is not currently used on any USAF operational platforms, but it will be incorporated into Global Hawk in the future.³⁴

Passive Sensors

Because of active sensor limitations, passive sensors are incorporated into the process. A passive sensor does not transmit, but only receives. Examples of passive

³¹ Joint Publication 1-02, DOD Dictionary of Military and Associated Terms, 12 April 2001, real-time means the data has only been delayed for electronic communication with no noticeable delays, 355.

³² Joint Publication 1-02, DOD Dictionary of Military and Associated Terms, 12 April 2001, near-real-time means that the data or information has only been delayed for electronic communication and automatic data processing, implying no significant delays, 292; Alan Vick et al., 17.

³³ Ibid.

sensors are Electro-optical (EO) sensors, thermal imagers, and signal intelligence (SIGINT) equipment.

EO sensors are the most common type of airborne passive sensor and can be used to detect, locate, and identify COIs.³⁵ EO sensors are camera-like devices that operate in the long-wave infrared (IR) through the ultraviolet region of the electromagnetic spectrum.³⁶ Because of this fact, EO sensors offer higher resolution than other types of sensors, but they are also more dependent on weather conditions.

EO sensors are routinely used on space vehicles and high-flying aircraft like the U-2R and RQ-4A Global Hawk. One vehicle, the KH-11 satellite gathers information and then sends the image to a ground site where it is processed in near-real-time.³⁷ Depending on atmospheric conditions and COI contrast, the KH-11 can detect objects as small as six inches.³⁸ For example, an EO sensor can distinguish between a truck with a .50-caliber machine gun on its roof and one without.³⁹ One significant drawback of these platforms, however, is their inability to deliver the imagery when needed.

Because most EO satellites are in low earth orbit (LEO), flying between 60 and 600 miles above the surface to enable them to see small areas quite clearly, they are not continuously over a specific area on the earth's surface.⁴⁰ This results in delays from when a COI is detected to when a satellite passing overhead can identify it. For this

³⁴ Kathy Dimaggio et al., "Presence with an attitude!" *United States Naval Institute Proceedings*, October 2000, n.p., on-line, Internet, 15 October 2001, available from <http://proquest.umi.com>.

³⁵ Alan Vick, et al., *Enhancing Air Power's Contribution Against Light Infantry Targets*, 21.

³⁶ *Ibid.*, 20.

³⁷ Jeffrey T. Richelson, "High Flyin' Spies," *Bulletin of the Atomic Scientists* 52, no. 5 (September/October 1996), n.p., on-line, Internet, 09 January 2002, available from <http://www.thebulletin.org/issues/1996/so96/so96richelson.html>.

³⁸ *Ibid.*

³⁹ Recent operations in Afghanistan highlighted this fact. Major David Hathaway, CENTAF's Chief of Strategy, interview by author, 30 Nov 01.

⁴⁰ Kimberly M. Corcoran, "Higher Eyes in the Sky: The Feasibility of Moving AWACS and JSTARS Functions into Space," (master's thesis, School of Advanced Aerospace Studies, October 1999), 14.

reason, the “USAF and the National Security Agency (NSA) have concluded [that] too much emphasis has been placed on low and medium orbit satellites that cannot watch a target for more than a few tens of minutes at a time.”⁴¹ The U-2R also faces similar problems due to required overflight and limited endurance. In addition, the U-2R's EO images are not downlinked to ground stations, but instead must be downloaded from the aircraft upon landing, many times well after the critical COI identification was needed.⁴² Although the RQ-4A Global Hawk is a long-endurance UAV with a loiter of up to 24 hours, it is just now coming on line and has so far proven itself unreliable.⁴³ Another disadvantage of EO sensors is their dependency on favorable atmospheric conditions

Rain, haze, clouds, humidity, smoke, and dust all work to degrade EO's ability to provide the necessary resolution to accurately identify a target. Considering that historical meteorological data shows that in three of the four primary theaters (PACOM, EUCOM, and SOUTHCOM) poor weather is a factor fifty percent of the time, EO's ability to deliver imagery may be severely hampered.⁴⁴ Also, EO sensors are limited in identifying camouflaged targets. One technique that helps to alleviate EO's limitations is the use of multispectral imaging.

A multispectral approach overcomes atmospheric effects and targets hidden by camouflage by combining the visible, IR, and other segments of the electromagnetic spectrum into a coherent picture. Because the approach uses a several different spectral

⁴¹ David A. Fulghum, "New Air Force Recce Aircraft Takes Shape," *Aviation Week & Space Technology*, 26 November 2001, 34.

⁴² Lt Col Jack Jones, 36th Intelligence Squadron Commander, interview by the author, 05 March 2002. Recent changes allow some U-2s to data link digitized pictures in near-real-time to ground stations, but it still takes at least 15-20 minutes to get the information to the user (i.e., the AOC).

⁴³ Paul Richter, "Global Hawk Crashes in Afghanistan in a Setback for High-Tech Drones," *Los Angeles Times*, 01 January 2002, n.p., on-line, Internet, 16 February 2002, available from <http://www.globalsecurity.org/org/news/2002/020101-attack01.htm>.

wavelengths, objects that are indistinguishable in the one spectrum can now be easily detected and identified in one of the others. Unfortunately, US intelligence was slow to recognize the need for this technology and, running into budgetary roadblocks, was later forced to buy the service from commercial sources.⁴⁵

Another type of passive sensor uses infrared imaging, and it detects differences in temperature between an object and its background. Due to the normal heating and cooling processes that occur from the sun's rising and setting, objects heat up and cool down at different rates because of their differences in specific heat.⁴⁶ For example, because armor has a higher specific heat value than foliage, an armored tank will stay hot well into the night while foliage will quickly cool with its surrounding environment. The resulting difference in temperatures allows a thermal imager to detect objects that EO systems cannot, including many camouflaged targets.

In order to increase resolution to allow discrimination between objects and their backgrounds, thermal imagers use NFOVs. For this reason, they are not good for detecting COIs, but can locate a COI if cued. Thermal imagers can also identify COIs, but again, they must be close to the object in order to get sufficient resolution to make an assessment. Factors that degrade thermal imagers are clouds, rain, humidity, snow, and wind. One sensor that overcomes many of these limiting factors is SIGINT.

SIGINT intercepts communications signals including voice, fax, telex traffic, and a variety of electronic signals such as the emanations of radar systems.⁴⁷ Since most signals have very distinct signatures, SIGINT's main advantage is its ability to identify its

⁴⁴ Headquarters, Air Combat Command, *Combat Air Forces Global Attack Mission Area Plan - FY2002*, 01 October 2000, 15.

⁴⁵ Richelson, n.p.

source. For example, SAM radars operate in very specific frequency ranges, with unique operating characteristics. With some experience, it becomes very easy to not only detect the SAMs radar emission, but also identify exactly what kind of radar (and, therefore, the kind of SAM) it is. SIGINT's two weaknesses are the requirement for an enemy to transmit over the "air" in order to detect the signal, and its inability to locate a system quickly and accurately.⁴⁸

SIGINT locates a target through a process of triangulating signals emanating from a COI. As the SIGINT platform moves in relation to the COI, it continually triangulates and refines its assessment of the COI's location. Over time the COI's location becomes more and more precise until the sensor's threshold is met, which is the best accuracy the sensor can deliver. From this point onward, regardless of how much time is spent triangulating a COI, no improvement in accuracy will result.⁴⁹

Because SIGINT sensors do not need to be placed close to an object to obtain high-resolution, such as required by EO sensors, they can be placed on satellites in high geostationary orbits that allow for continuous coverage of an area.⁵⁰ For this reason, SIGINT satellites placed into high orbits do not have the on-station problems encountered by their EO brethren, a real advantage. SIGINT sensors are also placed on aircraft. Two aircraft specifically designed for collecting SIGINT are the USAF's RC-135V/W Rivet Joint and the Navy's EP-3 Aries. The Rivet Joint is a modified Boeing C-135 airframe

⁴⁶ Specific heat is defined as the amount of heat necessary needed to move 1 gram of a substance 1 degree Celsius. Available from <http://www.dbhs.wvusd.k12.ca.us/thermoschem/specific-heat.html>, 16 Feb 2002.

⁴⁷ Richelson, n.p.

⁴⁸ Since SIGINT sensors only listens to the enemy's emissions, they cannot intercept messages or information sent via optical cable, normal telephone lines, or other methods where direct connectivity is used.

⁴⁹ Danskine, 43.

⁵⁰ Geostationary orbits are located approximately 22,300 miles from the earth, allowing them to orbit in constant relation to the earth's surface; Corcoran, 14.

that can fly for eleven hours at a time without air-to-air refueling (AAR), or 20 hours with AAR, all the while collecting information. The EP-3 is a modified P-3 four-engine turboprop aircraft that has greater than twelve-hour endurance, giving it a range of over three thousand miles.⁵¹

Fusion

Fusion is the process of "combining data gathered during the detect, identify, and locate functions to develop targeting information."⁵² While fusion can be done at the tactical level, such as a pilot flying along and detecting a tank, identifying it as a hostile, and then attacking it, the fusion necessary at the ISR and C2 level involves the rapid exchange of information between platforms and sensors to gain an accurate picture of the battlespace. According to Joint Publication 3-55, "the better the interoperability of systems and the more robust and redundant the links, the better the cross-cueing, analytical exchange, and ability of the commander to work inside an opponent's decision loop."⁵³ In essence, fusion is the key enabler that allows all the different sensor capabilities to be utilized and integrated into a common picture. Unfortunately, however, many of the key ISR sensors and platforms discussed earlier do not communicate with each other, leaving operators grasping to gather the bits of information single-handedly. This is why Gen John P. Jumper, USAF chief of staff, wants a "system of systems"

⁵¹ Federation of American Scientists, "Rivet Joint," on-line, n.p., Internet, 21 November 2001, available from http://www.fas.org/irp/program/collect/rivet_joint.htm; Federation of American Scientists, "EP-3 Aries," on-line, n.p., Internet, 16 February 2002, available from http://www.fas.org/irp/program/collect/ep-3_aries.htm.

⁵² Danskin, 18.

⁵³ Joint Publication 3-55, Doctrine for Reconnaissance, Surveillance, and Target Acquisition Support for Joint Operations, 14 April 1993, II-5.

approach that will break-down the "tribal barriers" and allow information to pass freely between platforms, resulting in faster decisions, and, therefore, a faster kill chain.⁵⁴

After analyzing the various active and passive sensor capabilities along with the problem of fusion, Table 1 is deduced. A quick glance at Table 1 reveals two potential problems. First, detecting a hidden, stationary target that does not emit is very difficult. Other than using multispectral imagery, SAR, and EO techniques, all of which are inefficient at best, there is little that can be done to solve the problem. In most cases, however, the enemy must come out of hiding to effectively engage US forces, which then allows MTI to detect it. In this case, one must not only detect, locate, and ID the COI as a target, but then proceed through the rest of the kill chain to destroy it before it can act against friendly forces. As was realized in Desert Storm, a SCUD TEL can set-up, shoot, and scoot in 35-45 minutes, making this a very difficult task.⁵⁵ In other cases, however, where an enemy may not need to move, a SCUD TEL may not be located until after its missile is launched and detected by a Defense Support Program (DSP) Satellite or a Cobra Ball RC-135 aircraft.⁵⁶ With a SCUD TEL capable of leaving its launch site

⁵⁴ Gen John P. Jumper, chief of staff, US Air Force, address to the AFA's 17th annual Air Warfare Symposium, Orlando, Florida, 15 February 2001.

⁵⁵ Mike Lukes and Eugene McKenzie, "Theatre Missile Defense (Attack Operations) for those Tactically Challenged," (concept paper on Knowing Your Enemy, 30 September 1997), 7.

⁵⁶ DSP satellites are located in geosynchronous orbit 22,300 miles above the earth and are capable of detecting missile launches by observing their heat signature during boost phase. The system, deployed in 1970, will soon be replaced by the Space Based Infrared System (SBIRS). "Defense Support Program," USAF Space Command Fact Sheet, n.p., on-line, Internet, 25 February 2002, available from <http://www.spacecom.af.mil/hqafspc/library/facts/dsp.html>; Federation of American Scientists, "Joint Surveillance Target Attack Radar System," on-line, n.p., Internet, 26 February 2002, available from http://www.fas.org/irp/program/collect/cobra_ball.htm. Cobra Ball is a modified RC-135 specifically designed to detect and track tactical ballistic missile (TBM) during their boost phase. Within seconds of launch, the system provides estimates of launch point, intercept point, and impact point that can be data linked to other C2 platforms.

within five minutes of firing, the rest of the kill chain must now be accomplished even faster than before, preferably within single-digit minutes.⁵⁷

Table 1
Summary of Sensor Capabilities^a

Type Sensor	Detect	Locate	ID
<u>Active</u>			
SAR	-	+	-
MTI ^b	+	+	-
FolPen ^c	o	+	-
<u>Passive</u>			
EO	-	+	+ ^d
Multispectral	o	+	o
IR	-	+	+ ^d
SIGINT	+	-	+

^aPlus (+) is favorable, minus (-) is unfavorable, and zero (o) is neutral.

^bObject must be moving.

^cIsolated areas of heavy foliage.

^dRequires favorable atmospheric conditions and close sensor range.

The second revelation is that the timely identification of a non-emitting target will be difficult, especially in poor weather conditions. This fact is compounded because the enemy will try to avoid emitting any signals. One example of this is evidenced when enemy SAM systems minimize their emission times for fear of being detected and

⁵⁷ Gen John P. Jumper, 15 February 2001. Gen John Jumper's goal is to destroy TCTs in "single-digit minutes" after detection.

destroyed. Unlike most SAMs, however, not all TCTs have to emit to engage their prey, even when their traditional lines of communication are degraded.⁵⁸ One solution routinely used is to send manned aircraft into the area to identify the COI as hostile or friendly, and then attack it if the rules of engagement (ROE) permit.⁵⁹

While this method is an option, it is inefficient because it requires a commitment of valuable resources that may end in futility if the COI, once identified, is not a target. In essence, all of the time and effort used in the operation is for naught, serving only to squander and expose manned aircraft that could have been used for other missions. This is why Gen Wesley Clark, JFC in Operation Allied Force, said, "The US armed forces are unbalanced. They are over-structured in strike platforms and under-resourced for the amount of ISR it [sic] possesses."⁶⁰ Attempting to alleviate General Clark's complaint, the USAF has recently developed and integrated the RQ-1 Predator into the kill chain.

Because it is equipped with NFOV sensors that provide excellent resolution, once cued, the RQ-1 Predator can locate and identify COIs.⁶¹ To accomplish this, the Predator is flown to the COI's location and then peers down taking high-resolution video of the COI. The data is then downlinked through the Joint Broadcast System (JBS) in real-time to the Air Operations Center (AOC) where the COI is identified.⁶² Now, unlike times when manned air assets were tasked before knowing the probable outcome, they are

⁵⁸Michael R. Gordon and General Bernard E. Trainor, *The General's War* (NY.: Little, Brown and Company, 1995), 247.

⁵⁹ ROE are directives issued by competent military authority that delineate the circumstances and limitations under which US forces will initiate and/or continue combat engagement with other forces encountered. Joint Pub 1-02, 12 April 01, 371.

⁶⁰ Keith Hutcheson, ed., *Unified Aerospace Power in the New Millenium* (Washington, D.C.: HQ USAF/XPX, 7-8 February 2001), 13.

⁶¹ Haun, 84.

⁶² Joint Pub 1-02, 18. The AOC is the JFACC's command center for controlling his air assets; Federation of American Scientists, "RQ-1 Predator," on-line, n.p., Internet, 28 November 2001, available from <http://www.fas.org/irp/program/collect/predator.htm>.

efficiently used only against a confirmed target. This is why Gen John P. Jumper, chief of staff of the Air Force stated, "We're now using our ISR sets more to confirm that which we predicted than for pure discovery."⁶³ The major flaw with this plan, however, is the Predator's inability to fly quickly to the unidentified COI, slowing down the entire process.

Utilizing a pusher-type propeller and a Rotax 912 engine, the Predator flies at a "blistering" cruise speed of 70-90 knots.⁶⁴ At this speed, it takes the Predator over an hour to fly only one hundred miles. Since even small countries like Afghanistan are several hundred miles across, many Predators spread geographically across the area are required to provide timely information. Although this is not horrible in itself, it does raise cost and survivability concerns.

Although the Predator has a service ceiling of 25,000 feet, it routinely loiters at 15,000 feet or lower to capture the high quality video needed to accurately identify targets.⁶⁵ Thus, the Predator is vulnerable to ground fire, particularly anti-aircraft artillery (AAA). This was demonstrated during the Predator's first European deployment in 1995 (Nomad Vigil) where AAA shot down two Predators.⁶⁶ Since then, the USAF has lost over nineteen Predators, with a rash of losses recently occurring in Operations Southern Watch and Enduring Freedom.⁶⁷ Previously, the USAF was procuring six to seven Predators per year to compensate for normal attrition, but with the recent increase in losses, the USAF has allocated \$161 million in the proposed 2003 budget to buy 22

⁶³ Gen John P. Jumper, chief of staff, US Air Force, address to the National Defense Industry Association, Langley AFB, Virginia, 27 June 2001.

⁶⁴ Federation of American Scientists, "RQ-1 Predator," n.p.

⁶⁵ Robert Wall, "Recce Plans Bolstered in Terror's Wake," *Aviation Week & Space Technology*, 29 October 2001, 61.

⁶⁶ Federation of American Scientists, "RQ-1 Predator," n.p.

⁶⁷ Wall, 61.

more Predators at a cost of about \$7.3 million each.⁶⁸ This fact is startling considering the Predator was originally designed to be a relatively low cost air vehicle of about \$3 million each.⁶⁹ In order to reduce the losses, the USAF has considered changing flight routes to reduce the Predator's predictability, and encrypting its communications links to make it harder to sever or disrupt the remote control of the aircraft.⁷⁰ Even these modifications do not remove the root cause of the problem.

In the end, the Predator provides a much-needed capability that allows the JFACC to efficiently allocate air resources to kill confirmed targets, not COIs. With the Predator's cost increasing to over \$7 million a copy, however, commanders may think twice before putting them into harm's way, especially since they fly low and slow, and have proven themselves very vulnerable to ground fire. At the very least, commanders will most likely recognize that a Predator underutilized (staying out of known threat rings) is better than having no Predator at all (i.e., shot down), which reestablishes the problem of timely and accurate COI identification that the Predator was supposed to solve.

Dissemination

Dissemination is "the link between sensors and shooters, and occurs when the final targeting information is passed to command and control agencies and the shooters for possible engagement."⁷¹ Before disseminating targeting information to a weapons platform five factors should be considered: effectiveness, responsiveness, range,

⁶⁸ Ibid.

⁶⁹ Ibid.

⁷⁰ Ibid.

⁷¹ Danskine, 19.

accuracy, and threat.⁷² The first four factors are dependent on the aircraft and its associated munitions; the last factor rests entirely on the target or COI's location in regard to the enemy's defenses. Effectiveness is the first consideration because there is little sense in attacking a target with a weapon that has a low probability of achieving damage. For example, tasking an F-15C air-to-air fighter equipped with a 20mm gun to attack a tank would result in little or no effect. For this reason, the aircraft selected to engage the target must have munitions appropriate for the amount of damage desired.⁷³

Response and range are the next two factors and relate to how soon an aircraft can deliver ordnance onto the target. As mentioned earlier, speed of attack is the critical factor needed to successfully destroy TCTs. For this reason, aircraft closer to the target are likely to be prioritized ahead of others located far away because they can strike sooner.⁷⁴

Accuracy is ability of the tasked platform to find the intended target and then destroy it. For instance, an aircraft using an unguided general-purpose (GP) 500-pound bomb (i.e., a Mk-82) to attack a dug-in tank has a low probability of success in comparison to a laser-guided 500-pound weapon (i.e., a GBU-12) because the accuracy of the latter is much better. Issues related to acquiring the desired target will be addressed in the next section, Level 2.

The last factor for consideration before disseminating target information to a strike package is the threat. As mentioned earlier, many times TCTs are located behind heavy air defenses that require support assets such as SEAD, electronic attack (EA), and

⁷² Normally a manned aircraft, but it could be any platform capable of delivering ordnance on the target; ALSA, II-5, 6.

⁷³ Ibid.

⁷⁴ Ibid.

offensive counter-air (OCA) aircraft to accompany the strike aircraft.⁷⁵ After considering all five of these factors, the targeting information is disseminated to the best asset(s) for the task.

Level 2 - The Shooter

Unlike Level 1 where the detect, locate, and identification functions may occur simultaneously, Level 2 is a sequential process that begins with ingress and ends with egress. Between these two boundaries are the tasks of finding, tracking, identifying, and delivering ordnance on a target.

Before an aircraft can deliver ordnance, it first must find the target. In order for an aircraft to reliably find a specific target, target location error (TLE) must be minimized.⁷⁶ This is to say that if an aircraft's sensors can scan a circular area of two nautical miles (nm) in diameter, then the TLE must be less than one nm to ensure it will be within the sensor's field of view (FOV). Because different tactical aircraft have different sensor FOVs, operators at Level 1 must take TLE into account when determining a suitable strike aircraft. Obtaining small values of TLE are not normally a problem with stationary targets located with SAR or EO techniques, but it can be a huge problem with moving targets or those detected with SIGINT.

The problem stems from the time delay occurring from when the target information is disseminated to when the strike aircraft arrives in the target area. Because even slow moving targets can travel significant distances in relatively short periods of time, they can be very difficult to find, especially in a high-threat area that does not permit aircraft to loiter and search for the target. One method used to overcome this

⁷⁵ Ibid.

challenge is for Level 1 platforms to update the target's whereabouts to the strike aircraft in real-time, keeping TLE in check, and enabling successful target detection by the strike aircraft.

When an aircraft finds a target, the next steps taken are to track and identify it. To track a target, tactical aircraft use many different sensors, some include passive SIGINT receivers, IR pods, radar, and, of course, the pilot's vision. One advantage to using aircraft sensors to track a target is the ability for the pilot to cue a BVR weapon to the track (i.e., an AGM-65 Maverick missile), lock it on to the target, and shoot without ever flying into harm's way. Because ROE many times require a pilot to identify a target before shooting, however, this advantage may be of little use.⁷⁷

Although SIGINT receivers can identify targets quickly, aircraft using IR and radar sensors cannot accurately identify a target until at relatively close range, usually well inside the maximum engagement range of their air-to-ground missiles.⁷⁸ This limitation is magnified by ROE altitude restrictions that keep aircraft flying high above small arms fire and shoulder-fired SAMs. In Kosovo, for example, aircraft were usually required to stay above 15,000 feet above ground level (AGL), making target identification difficult by day and virtually impossible at night, even with IR targeting pods (TGPs) and night vision goggles (NVGs).⁷⁹ Later, however, after F-16CG forward air controllers (FACs) misidentified and bombed a Kosovar refugee column, the altitude was lowered to 5,000 feet (AGL) to help improve the chances of accurate target

⁷⁶ Air Force Pamphlet 14-210, Intelligence, 01 February 1998, 98. TLE is the difference between the target's actual location and the expected location.

⁷⁷ Haun, 82. Pilots in Kosovo were required to visually identify targets before engaging them. The same ROE is used in most air campaigns where fratricide and collateral damage are issues.

⁷⁸ SIGINT receivers used on tactical aircraft are normally designed for SEAD, shooting High Speed Anti-radiation Missiles (HARM) at emitting SAM systems, and have no use for non-emitting TCTs; Headquarters, Air Combat Command, 22.

identification.⁸⁰ According to Major General Barry, the requirement to accurately identify targets (to reduce collateral damage and fratricide) is going to persist in the future.⁸¹

Level 2A - The Weapon

Although Level 2A, the weapon, is presented as its own, distinct level, notice there is no horizontal line on Figure 1 that separates Level 2 from Level 2A. This signifies that while the transition from Level 1 to Level 2 involved a major change requiring the tasking of strike and suppression aircraft, the transition from Level 2 to 2A is small and easy. In fact, it is simply the continuation of Level 2, but now in regard to the weapon. The three steps in Level 2A are find, track, and kill, and they are dependent on the type of weapon used to engage the target.

If employing unguided bombs, where the bomb falls ballistically to the ground without further guidance, the kill chain proceeds from "deliver" directly to "kill." In essence, once the bomb comes off the aircraft, it free-falls through the air until impacting the ground. While GP bombs are cheap and plentiful, they are inherently inaccurate and have little capability to hit moving targets. Similar to throwing a rock at a moving target, the successful engagement of moving targets with GP bombs necessitates predicting the target's future location and then bombing that location in hopes that the target cooperates. While this may be simple for a target twenty yards away, the bomb range for an aircraft at 20,000 feet AGL is four to five miles, resulting in a time of flight of almost a minute.⁸²

⁷⁹ Haun, 82.

⁸⁰ Ibid.

⁸¹ Hutcheson, 42.

⁸² Bomb range is the horizontal distance across the ground the bomb must travel, measured from the bomb's release point to the target; 27th Fighter Wing Attack Guide (WAG), May 1995, 54.

This fact makes hitting moving targets with unguided bombs a matter of luck, and it is a reason why acquire before launch (ABL) munitions were developed.

ABL munitions are those weapons that require target coordinates or a self-track of the target before releasing them from the aircraft. Some of these weapons, like the Joint Direct Attack Munition (JDAM) and the Conventional Air Launched Cruise Missile (CALCM), are programmed to fly to a fixed point (i.e., latitude and longitudinal coordinates) on the ground. Once launched, these weapons guide to their point using inertial navigation linked with Global Positioning System (GPS) updates.⁸³ Unfortunately, since there is no capability to change the weapon's flight profile once released, they, like GP bombs, are of little use in attacking mobile targets. Some other ABL munitions, however, like the AGM-65D/G Maverick, specialize in attacking mobile targets.

The AGM-65D/G incorporates an IR tracking assembly on the front of the missile that allows it to track a target all the way until impact.⁸⁴ To employ the missile, the pilot simply locks the missile seeker onto the target and then shoots the missile when in range. Because the missile continues to track the target from launch to impact, target maneuvering has no effect on its accuracy. For this reason, the AGM-65 is the weapon of choice for moving vehicles, especially armor. The major disadvantage with the Maverick, however, is its limited target acquisition range. Typical lock-on ranges are anywhere from four to eight miles, depending on atmospheric conditions and the target's temperature contrast. For this reason, strike aircraft employing Maverick will likely need

⁸³ Federation of American Scientists, "Joint Direct Attack Munition (JDAM)," on-line, n.p., Internet, 18 February 2002, available from <http://www.fas.org/iman/dod-101/sys/smart/jdam.htm>.

⁸⁴ Federation of American Scientists, "AGM-65 Maverick," on-line, n.p., Internet, 18 February 2002, available from <http://www.fas.org/iman/dod-101/sys/smart/agm-65.htm>.

suppression aircraft to accompany them into hostile enemy territory. One alternative to increase standoff is to use an acquire after launch (AAL) munition.

AAL munitions fly long distances to the target area and then perform a search of the area to find, track, and kill mobile targets. In essence, there is very little theoretical difference between an ABL munition that flies to a fixed point and an AAL munition that performs the same function up to a point. However, upon arrival at the fixed point, the AAL munition performs an area scan to find the target. The problem with AAL munitions has not been their ability to find or track a target, but to identify it.⁸⁵ In the past, Automatic Target Recognition (ATR) systems have not identified targets accurately and have stunted the development of AAL munitions.⁸⁶ One future AAL weapon, the Low Cost Autonomous Attack System (LOCAAS), will be discussed later in Chapter 3.

Killing the target is the final step in Level 2A. Targets are normally engaged to achieve levels of damage that range from a catastrophic kill (sometimes referred to as a K-kill), to a mobility kill, or to a firepower kill.⁸⁷ Each level of damage is usually best achieved with a certain type of munition, and the probability of achieving that level of damage usually increases with the amount of ordnance delivered. For example, to achieve a catastrophic kill against a tank, it is best to use big weapons (i.e., Mk-84 2,000 pound bombs) that can be delivered accurately. A Mk-84 is a good choice because it offers both fragmentation and blast effects that are well suited to destroy a tank. Up to a point of diminishing returns, the more weapons delivered; the greater the chance of

⁸⁵ DARPA Special Projects Office, "Jigsaw Project Concepts," n.p., on-line, Internet, 30 November 2001, available from <http://www.DARPA.mil/SPO/Solicitations/BAA01-15/JIGSAW-Concepts.htm>.

⁸⁶ David C. Hathaway, "Germinating a New SEAD: The Implications of Executing the SEAD Mission in a UCAV," (master's thesis, School of Advanced Aerospace Studies, June 2001), 51.

⁸⁷ A catastrophic kill means the target is inoperable and beyond repair; A mobility kill means the target cannot move on its own accord for a given length of time; A firepower kill means the target is incapable of delivering ordnance for at least four hours.

achieving the desired ends. Unlike catastrophic kills that require heavy blast and fragmentation, firepower kills are best achieved with cluster bombs. Cluster bombs contain many submunitions that are expelled in flight and disperse to cover a large surface area. Because the submunitions are small, they usually have only enough explosives to create light damage to a tank. The light damage is frequently severe enough to disable the gun or targeting systems to such a degree that the result of the attack is a firepower kill. So even though the vehicle may remain mobile or mostly functional, it is unable to engage. On other types of soft vehicles, however, cluster bombs may achieve catastrophic kills. While this may seem difficult and puzzling considering the multitudes of weapons and targets, planners use a computer program called the Joint Munitions Effectiveness Manual (JMEM) to help match the correct weapon to the target for the desired level of damage. In addition, the program provides estimates on the number of bombs (and, therefore, the number of aircraft) required to achieve a specific probability of damage against a given target.

Level 3 - BDA

The last step in the kill chain is BDA. BDA is "the timely and accurate estimate of damage resulting from the application of military force, either lethal or non-lethal, against a predetermined objective."⁸⁸ BDA is important because it supports the commander's decision-making process, providing the necessary feedback to make adjustments in their operational plan.⁸⁹ In essence, "[w]hen the decision to attack a particular enemy unit is tied to reducing it to a predetermined strength prior to our

⁸⁸ Joint Publication 1-02, 50.

⁸⁹H. Brock Harris, "Counterfire and Predictive BDA," *Military Intelligence*, April-June 1998, 42.

crossing the line of departure, the BDA estimates must be timely and accurate."⁹⁰ In Desert Storm, however, BDA sometimes took twelve days to obtain, ultimately creating a misunderstanding of how weak and ineffective the Iraqi forces really were, and it "may have resulted in a concept of ground operations that allowed significant elements of the Republican Guard to escape."⁹¹ To avoid such problems in the future, prospective systems should incorporate BDA into their processes, and this concept will be considered in this study.

Chapter Summary

This chapter laid the groundwork for the rest of the analysis. A few conclusions can be made:

1. Inherent sensor limitations make detecting stationary targets difficult, especially if hidden. If such a target is detected, the remaining kill chain must then be accomplished quickly, optimally in less than 10 minutes.
2. Speeding through the kill chain is complicated by a lack of fusion to tie all the sensors together into a common architecture.
3. The inability to obtain timely and accurate identification at the ISR and C2 level slows the kill chain down and tends to waste valuable manned aircraft on non-productive missions.
4. While the Predator helps obtain timely identification of COIs, it is significantly limited due to speed and survivability concerns, not to mention cost.

⁹⁰ Ibid.

⁹¹Mark C. Nowland, "Eliminating the Rhetoric: An Evaluation of the Halt-Phase Strategy," (master's thesis, School of Advanced Aerospace Studies, February 2001), 60.

5. Manned aircraft can be used to identify and strike TCTs, but they may need support aircraft, updated target information to keep TLE in check, and ROE that enable identification to occur.
6. Using manned aircraft lengthens the kill chain's timeline because of time and space factors.
7. GP bombs and ABL munitions (like JDAM and CALCM) are of little use for engaging moving targets.
8. Other ABL munitions (like AGM-65 Maverick) have a good capability to engage moving targets, but they require relatively close ranges to enable them to track the target.
9. AAL's ATR is not yet reliable, but looks promising and could enable aircraft to standoff and still engage moving targets.
10. BDA should be incorporated into the process, if practical.

Looking to solve the revelations presented above, Chapter 3 investigates reactive methods and their suitability for use.

Chapter 3

The Reactive Approach

We need a robust, time-critical targeting capability that turns our response to emerging targets from hours today into minutes in the future.

— Gen John P. Jumper
Chief of Staff, USAF

This chapter focuses on solving the problems presented in Chapter 2 by using a reactive approach. This approach uses the kill chain sequence presented earlier where one first detects a COI, and then reacts to it by going through the rest of the chain as fast as possible. This approach does not endorse predictive targeting where one would employ weapons before detecting a COI (i.e., place loitering weapons over an area prior to detecting a COI). In essence, the reactive approach does not attempt to reduce or consolidate the number of steps in the kill chain, but instead attempts to speed through them by eliminating the bottlenecks presented earlier. This chapter evaluates the efficacy of this approach regarding TCTs by answering three questions: 1) Are there new ISR platforms that can detect, locate, and identify TCTs more efficiently? 2) What can be done to fuse sensor data into a common battlespace picture? and 3) What future platforms and weapons are best suited to reactively attack TCTs?

Future ISR Capability to Detect and identify

As mentioned in Chapter 2, progressing quickly through the kill chain is currently hindered because ISR platforms (Joint-STARS, Rivet Joint, and space assets) cannot identify non-emitting TCTs or efficiently detect stationary COIs, resulting in the use of either manned aircraft or the Predator to fill the void. As previous evidence showed,

however, neither of these options is very efficient. While this approach has been necessary due to the lack of other means, must the ill-suited approach continue to be used based on ISR's prognosis to detect and identify TCTs in 2010? According to the Aerospace Command and Control and ISR Center (AC2ISRC), ISR's prognosis is dependent on three programs the USAF is currently pursuing to solve this issue: 1) the Multi-platform Radar Technology Insertion Program (MP-RTIP), 2) Global Hawk, and 3) the Space-Based Radar (SBR).⁹²

MP-RTIP

The MP-RTIP evolved from the Joint-STARS Pre-Planned Product Improvement (P3I) effort to design, develop, install, and test advanced radar systems that could be integrated into Joint-STARS.⁹³ Looking ahead and seeing a need for advanced radars on Global Hawk and a NATO medium-sized ISR platform (still in development), the USAF redesigned the program to develop advanced radar for use on a variety of platforms. In December 2000, Northrop Grumman received a three-year \$303 million contract to design the MP-RTIP system.⁹⁴ After the design work is completed, the next phase will develop and test the system. According to the AC2ISRC, the advanced radar should be ready for implementation about FY2008.⁹⁵

⁹² Teresa A.H. Djuric, *Future Command and Control of Aerospace Operations*, Strategy Research Project, (Carlisle Barracks, PA.: US Army War College, 15 March 2001), 6. The USAF created the AC2ISRC in 1998 to pursue technology and systems that would eliminate chokeholds and speed up the kill chain; "Multi-Sensor Command and Control Constellation Team Effort," *AC2ISRC's C2ISR Legacy Roadmap*, slide 9, on-line, Internet, 18 February 2002, available from http://www.dpaas.com/Day2/Col%20gary%20connor%20multi_sensor%20command%20and%20control.ppt.

⁹³ Federation of American Scientists, "Joint Surveillance Target Attack Radar System," on-line, n.p., Internet, 28 November 2001, available from <http://www.fas.org/irp/program/collect/jstars.htm>.

⁹⁴ "Northrop Grumman Team Awarded \$303 Million Contract for Multi-Platform Radar Technology Insertion Program," Northrop Grumman News Release, 11 December 2000, n.p., on-line, Internet, 18 February 2002, available from http://www.northgrum.com/news/news_releases/1200-181_mprtip.html.

⁹⁵ "Multi-Sensor Command and Control Constellation Team Effort," slide 9.

Although little is known about the actual specifications and how it will work, the new radar will dramatically increase the USAF's ability to detect, track, and identify both stationary and moving ground vehicles from standoff orbits.⁹⁶ If the new radar follows the techniques planned for the original Joint-STARS P3I, enhanced SAR (ESAR), inverse SAR (ISAR), and High Range Resolution (HRR) MTI, at least a six-fold enhancement of the current radar's resolution would be obtained for both stationary and moving targets, significantly improving identification capability.⁹⁷ In order to take full advantage of MP-RTIP's capabilities, however, it will need to be placed in orbits that will minimize obstructions to its line-of-sight (LOS).

Since radar cannot look through terrain, standoff platforms such as Joint-STARS cannot observe enemy movement behind mountains or in rough terrain where deep gullies and culverts exist. By placing the radar high overhead, however, obstructions to the radar's LOS are nullified because the radar now peers straight down to the ground without hindrance. One high-flying platform well suited to this task is the Global Hawk.

Global Hawk

Global Hawk is the second avenue the USAF is pursuing to detect, locate, and identify TCTs, and, although currently unreliable, it should prove itself capable in time.⁹⁸ The Global Hawk is a high altitude, long-range, long-endurance unmanned platform that carries a 1,950 pound payload for up to thirty-six hours.⁹⁹ Operating at ranges up to

⁹⁶ "Northrop Grumman Team Awarded MP-RTIP Contract," *Northrop Grumman News Release*, 19 February 200, on-line, Internet, 21 November 2001, available from http://www.northgrum.com/news/rev_mag/review11/busfocus/mprtip.html.

⁹⁷ Federation of American Scientists, "Joint Surveillance Target Attack Radar System," n.p.

⁹⁸ Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap* (Washington, D.C.: Department of Defense, April 2001), 4. The Global Hawk was not expected to become operational until FY05. Because of the opportunity to use Global Hawk in Afghanistan, the USAF opted to exercise the technology before it fully matured, leading to some setbacks.

⁹⁹ Ibid.

3,000 nm from its launch area and cruising above 60,000 feet AGL close to an area of interest (AOI), LOS problems are minimized.¹⁰⁰ In scanning for prey, the Global Hawk uses a multitude of sensors.

Global Hawk's sensors include EO, IR, SAR, and MTI which enable it to detect, locate, and identify COIs in either real-time or near real-time. As the data is collected, it is distributed via LOS communication links to the Mission Control Element (MCE) by X-band or, if LOS is not available, by SATCOM.¹⁰¹ Using its radar and EO and IR sensors, the Global Hawk can search up to 40,000 square nm per mission at one-meter resolution and up to 1,900 spot images per mission at 0.3-meter resolution.¹⁰² Another sensor that promises to dramatically help identify COIs is hyperspectral imaging, and, because of this fact, the USAF desires to incorporate it into Global Hawk.¹⁰³

An extension of multispectral imaging, hyperspectral imaging measures the reflected energy from objects on the ground using hundreds of different frequencies in the spectrum.¹⁰⁴ Once the energy is collected, mathematical algorithms are used to process, differentiate, and combine the data into a coherent picture.¹⁰⁵ The technique is especially useful to find hidden objects and to discriminate between actual targets and decoys. To develop the technology, two projects are currently in place. First, the Air Force Research Laboratory (AFRL) is working on a project known as Spectral Infrared Remote Imaging Transition Testbed (SPIRITT). The program's purpose is to develop

¹⁰⁰ Federation of American Scientists, "RQ-4A Global Hawk," on-line, n.p., Internet, 21 November 2001, available from http://www.fas.org/irp/program/collect/global_hawk.htm.

¹⁰¹ Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap*, 4.

¹⁰² Ibid.

¹⁰³ Maj Gen Robert F. Behler, Commander AC2ISRC, US Air Force, address to the 5th President's Forum, ESC Conference Center, Hanscom AFB, Mass., 13 December 2001.

¹⁰⁴ Alan Vick, et al., *Enhancing Air Power's Contribution Against Light Infantry Targets*, (Washington, D.C.: RAND, 1996), 16.

hyperspectral imaging sensors and will begin testing the technology in 2003 using NASA's WB-57 high-flying aircraft.¹⁰⁶ The second program is the MightySat II.1 Space-Based Experimental Platform. The satellite, built by Spectrum Astro, Inc., of Gilbert, Arizona, weighs 300-pounds and incorporates a hyperspectral space-imaging instrument built under contract by the Kestrel Corporation. The instrument is the Department of Defense's (DoD) only space-based hyperspectral imager to use a Fourier Transform technique to discriminate between spectrally unique objects.¹⁰⁷ Provided neither program encounters any major setbacks, hyperspectral imaging for military applications should be available for use by the end of the decade.¹⁰⁸

Because it flies at very high altitudes, one of the advantages of Global Hawk over the Predator is its ability to avoid hostile ground fire. Since most AAA and shoulder-fired SAMs can only engage targets up to about 20,000 feet AGL, an area where the Predator routinely flies, the Global Hawk operates well above this threatening region and is unhindered by such weapons. In fact, only radar-guided SAMs and high altitude interceptors have the capability to reach Global Hawk at 60,000 feet, and to help account

¹⁰⁵ "The Warfighter's Edge: First Hyperspectral Images From Space," *Space Daily*, 08 September 2000, n.p., on-line, Internet, 20 February 2002, available from <http://www.spacedaily.com/news/radar-00e.html>.

¹⁰⁶ "That's the SPIRITT," *Beyond 2000*, 01 January 2001, n.p., on-line, Internet, 18 February 2002, available from http://www.beyond2000.com/news/Jan_01/story_988.html.

¹⁰⁷ Eric W. Weisstein, "Books about Fourier Transform Spectroscopy," *Wolfram Research*, n.p., on-line, Internet, 27 April 2002, available from <http://scienceworld.wolfram.com/physics/FourierTransformSpectrometer.html>. "Fourier Transforms were originally developed as an engineering tool to study repetitious phenomena such as the vibration of a stringed musical instrument or an airplane wing during flight. A Fourier transform spectrometer (abbreviated FTS) is a Michelson interferometer with a movable mirror. By scanning the movable mirror over some distance, an interference pattern is produced that encodes the spectrum of the source. Fourier transform spectrometers have a multiplex advantage over dispersive spectral detection techniques for signal, but a multiplex *disadvantage* for noise;" "MightySat II Satellites," *AFRL Fact Sheet*, July 1999, n.p., on-line, Internet, 20 February 2002, available from <http://vs.afrl.af.mil/factsheets/msat2.html>.

¹⁰⁸ "That's the SPIRITT," n.p.

for them, it uses electronic jammers and decoys for self-protection.¹⁰⁹ Nevertheless, with an estimated price of \$50 million each and considering that Global Hawk's electronic jammers and decoys will not be one-hundred percent effective in defeating all SAMs and air-to-air missiles, some degree of air superiority will most likely be required before flying Global Hawk in the face of such threats, especially since it is not stealthy.¹¹⁰ In the end, based on its ability to loiter, detect, locate, and identify COIs, Global Hawk may prove to be a worthwhile asset, but only commensurate with its ability to avoid enemy fighters and SAMs. A better approach that currently promises to practically eliminate all hostile fire is the utilization of space.

SBR

The last avenue the USAF is pursuing to solve current ISR limitations is the SBR. Given the advantages of space, namely free overflight, lack of obstructions to hinder LOS, and continuous coverage if enough satellites are used, space is the ultimate high ground.¹¹¹ Unfortunately, however, satellites also have disadvantages such as predictability due to their orbits, little flexibility to move or change orbits, a life span of about 10 years (much shorter than airborne vehicles), and the requirement of more sensor power since they are farther away from targets than are air-breathing assets.¹¹² In addition, when considering that studies have shown that anywhere from twenty-four to over one hundred satellites would be required for continuous coverage, the cost would

¹⁰⁹ Greg S. Lamb and Tony G. Stone, *Air Combat Command Concept of Operations for Endurance Unmanned Aerial Vehicles*, Air Combat Command CONOPS, 03 December 1996, n.p., on-line, Internet, 28 November 2001, available from http://www.fas.org/irp/doddir/usaf/conops_uav/toc.htm; David C. Hathaway, "Germinating a New SEAD: The Implications of Executing the SEAD Mission in a UCAV," (master's thesis, School of Advanced Aerospace Studies, June 2001), 17.

¹¹⁰ Office of the Secretary of Defense, *Unmanned Aerial Vehicles Roadmap*, 22. The DarkStar UAV program was to incorporate stealth, but it was cancelled in favor of the Global Hawk.

¹¹¹ Kimberly M. Corcoran, "Higher Eyes in the Sky: The Feasibility of Moving AWACS and JSTARS Functions into Space," (master's thesis, School of Advanced Aerospace Studies, October 1999), 1.

almost certainly be astronomical.¹¹³ Nevertheless, with Dr. Daniel Hastings, the USAF's Chief Scientist, reporting that to migrate Joint-STARS to space is technically feasible in the near term and with the cancellation of the Discoverer II technology demonstration program, the Secretary of Defense jump-started the acquisition of the SBR by formulating the 2001 Multi-Theater Target Tracking Capability (M3TC) Mission Needs Statement (MNS).¹¹⁴

The M3TC MNS sets the stage to develop and implement a space-based system that would enable multi-theater detection, tracking, identification, and targeting of ground moving targets by FY2010.¹¹⁵ To accomplish this feat, the radar will incorporate MTI, SAR, and Digital Terrain Elevation Data (DTED) techniques, and it promises to cover most of the earth.¹¹⁶ To develop the system, the SBR program will buttress on maturing technology and leverage advances made in the Discoverer II program. While the advantages of the SBR are obvious, can it be operational by 2010?

According to Major General Barry, the USAF's Director for Strategic Planning, the SBR is part of the USAF's Vision Force that will not be operational until about 2020.¹¹⁷ He goes on to say that because placing fully capable ISR platforms into space will not occur until after current ISR platforms wear out in 2014, the USAF will need an

¹¹² Ibid., 2.

¹¹³ Ibid., 20.

¹¹⁴ Ibid., 45; Allan Steinhardt, "Discover II Space Based Radar Concept," DARPA Tech 2000, slide presentation, on-line, Internet, 16 January 2002. Available from http://www.DARPA.mil/DarpaTech/presentations/tto_pdf/4steinhardtDIIIB&wrev1.pdf. The Discoverer II program was to design, fabricate, and launch two prototype MTI/SAR satellites to conduct a one-year effectiveness study on MTI, tracking, imaging, and DTED.

¹¹⁵ "Space-Based Radar EMD," *RDT&E Budget Justification Sheet*, June 2001, on-line, n.p., Internet, 22 February 2002, available from <http://www.dtic.mil/descriptivesum/Y2002/AirForce/0604251.pdf>.

¹¹⁶ "Space-Based Radar," USAF *Fact Sheet*, June 2001, on-line, Internet, 22 February 2002, available from http://www.losangeles.af.mil/smc/pa/fact_sheets/sbr.htm.

¹¹⁷ Keith Hatcheson, ed., *Unified Aerospace Power in the New Millenium* (Washington, D.C.: HQ USAF/XPX, 7-8 February 2001), 20.

intermediate platform to serve in the meantime.¹¹⁸ To fill this need, the USAF has proposed the MC2A, a modified Boeing 767-400 that will serve as a "battle management aircraft that would also take on missions now performed by the E-3 AWACS [Airborne Warning and Control System], E-8 Joint-STARS, and the EC-130 Compass Call."¹¹⁹ To develop and acquire the MC2A by 2010, the FY2002 House Defense Appropriations bill added an additional \$354 million over the budget request for production of two test aircraft and other related research.¹²⁰ With substantial investments pouring into the MC2A program, it is obvious that Major General Barry's foresight is correct, the SBR will not be fully operational by 2010, and until it is, the MC2A will help fill the C2ISR requirement.

Fusion - Can it be Done Better?

Chapter 2 illustrated that because no one sensor is fully capable in all operating environments, many different sensors are used to detect, locate, and identify COIs. With the current lack of communication between sensor platforms, operators are left to gather dispersed information single-handedly which hampers their ability to make quick decisions. Because decisions are not timely, progressing rapidly through the kill chain is difficult. Fusion solves this problem by combining vast amounts of data, sorting it, identifying the essential information, and then providing the pertinent information to the right operator quickly and efficiently.¹²¹ To implement fusion into its future ISR

¹¹⁸Corcoran, 2; John T. Correll, "The Vision Force," *Air Force Magazine*, November 2000, n.p., on-line, Internet, 10 October 2001, available from <http://www.afa.org/magazine/magz.html>.

¹¹⁹Robert Wall, "Recce Plans Bolstered in Terror's Wake," *Aviation Week & Space Technology*, 29 October 2001, 61.

¹²⁰"E-767 Multi-Mission Command and Control Aircraft," *Global Security*, n.p., on-line, Internet, 20 February 2002, available from <http://www.globalsecurity.org/military/systems/aircraft/e-767-mc2a.htm>.

¹²¹Edward F. Murphy et al., "Information Operations: Wisdom Warfare For 2025," research paper presented to Air Force 2025, on-line, n.p., Internet, 12 Oct 2001, available from www.au.af.mil/au/2025/volume1/chap01/v1c1-1.htm.

systems, the USAF is planning to use a concept called the multi-sensor, command and control constellation that will fuse together all the ground, air, and space multi-intelligence (human, signals, communications and measurement, and signature intelligence) platforms. The constellation referred to as MC2C (Multi-Command and Control Constellation), will tear down the barriers between individual systems and erect a horizontal architecture that allows sensor platforms talk to each other. To develop the MC2C, Maj Gen Jerry Perryman, a previous commander of the AC2ISRC, stated, "This complex task of creating the MC2C will require an aggressive, total team effort to meet the goal of having a flying prototype in 2008 with aircraft production beginning in 2009."¹²²

The components of the constellation are the MC2A, high and low altitude UAVs, and space (when operational), and they will replace the current capabilities delivered by AWACS, Joint-STARS, Rivet Joint, U-2, and the ABCCC (Airborne Battlefield Command and Control Center). As the battle management component, the MC2A will serve as the hub of the constellation and will use the Multi-Platform Common Data Link (MP-CDL) to connect all peripheral platforms into a common, horizontal architecture.¹²³

MP-CDL's goal is to provide a seamless and transparent global grid of information that all users can access. In order to achieve this goal, MP-CDL will transcend today's point-to-point data links with a multi-point connectivity system that allows a multitude of active (transmit and receive) users and an indefinite number of passive (receive-only) users. To ensure maximum participation, MP-CDL is scalable and

¹²² David A. Fulghum, "New Air Force Recce Aircraft Takes Shape," *Aviation Week & Space Technology*, 26 November 2001, 34; Todd Fleming and Chuck Paone, "Air Force Developing New 'Constellation' of Integrated Capabilities," *ESC Public Affairs and AC2ISR Center*, on-line, n.p., Internet, 05 December 2001, available from <http://www.hanscom.af.mil/Hansconian/Articles/05182001-1.htm>.

modular so it can fit on many different sized air and ground vehicles. Lastly, to keep the information flowing freely without compromise, the network is jam-resistant and secure. If the System Design and Development (SDD) phase and flight-tests go as planned, the MP-CDL should be ready for production and implementation in FY06.¹²⁴

ISR Section Summary

Based on the above discussion, there are a few tentative conclusions that can be made for ISR's capability in 2010:

1. New MP-RTIP sensors will most likely detect, locate, and identify COIs, but they will be limited in covering all AOIs due to standoff range limitations, LOS obstructions, or Global Hawk's inability to loiter because of the threat.
2. Because of these limitations, other sensor platforms will be needed to cover AOIs deep within enemy territory, behind terrain obstructions, or in high threat areas until the SBR becomes operational.
3. Improved fusion and streamlined battle management architecture will result in faster decision making, increasing the speed of progression through the kill chain.

Future TCT Attack Capability

Based on evidence and conclusions from Chapter 2, the ideal strike vehicle for engaging emerging TCTs would have the following characteristics and capabilities: (1) Fly and strike targets autonomously without the need for support aircraft (i.e., stealth), (2) Fly fast so as to cover distance quickly (i.e., be reactive), (3) Find, track, and identify

¹²³ Ibid.; Fulghum, 34.

¹²⁴ Rick Pierce, *Draft Rev 4 Systems Requirements Document for the MP-CDL*, ASC/RAJD, 25 Jan 02, n.p., on-line, Internet, 23 February 2002, available from http://www.pixs.wpafb.af.mil/pixslibr/mb-cdl/draft_mp_cdl_Rev%204_25Jan02%20.doc.

targets accurately (when applicable), (4) Deliver munitions capable of attacking and killing mobile targets, (5) Integrate easily with existing and planned systems, and (6) Be reasonably priced. The USAF is investigating a myriad of approaches to best satisfy these requirements. The most promising approaches are the LOCAAS munition, hypersonic delivery vehicles, the UCAV, and the Affordable Moving Surface Target Engagement (AMSTE).

LOCAAS

LOCAAS is a small miniature missile that was designed specifically for emerging TCTs. Its genesis stemmed from the elusive behavior of SCUD TELs that systematically evaded Coalition attempts to detect, locate, identify, and destroy them. During Operation Desert Storm, the first detection of a SCUD sometimes did not occur until a launch was observed by either a Defense Support Program (DSP) satellite or an RC-135 Cobra Ball. Once a launch was detected, these platforms calculated and predicted not only the SCUD's intended target, but also the missile's launch point. With this information available, the conceptualization for LOCAAS was forged.¹²⁵

In forging a design for LOCAAS, one hurdle to overcome was how to locate a fleeing target with a munition that cannot be redirected after launch. Because a SCUD TEL could leave its firing location within five minutes of shooting a missile, well before a LOCAAS would likely reach the SCUD's firing site, the munition would need to

¹²⁵ DSP satellites are located in geosynchronous orbit 22,300 miles above the earth and are capable of detecting missile launches by observing their heat signature during boost phase. The system, deployed in 1970, will soon be replaced by the Space Based Infrared System (SBIRS). "Defense Support Program," USAF Space Command Fact Sheet, n.p., on-line, Internet, 25 February 2002, available from <http://www.spacecom.af.mil/hqafspc/library/facts/dsp.html>; Federation of American Scientists, "Joint Surveillance Target Attack Radar System," on-line, n.p., Internet, 26 February 2002, available from http://www.fas.org/irp/program/collect/cobra_ball.htm. Cobra Ball is a modified RC-135 specifically designed to detect and track tactical ballistic missiles (TBM) during their boost phase. Within seconds of

perform an area search in order to find and kill its prey.¹²⁶ The size of the search area depended on the speed of the TCT fleeing its launch site and the time elapsed before the LOCAAS arrived on station. Table 2 displays the areas as a function of elapsed time for a 20-mph and 35-mph vehicle.¹²⁷

Table 2
LOCAAS Search Area for a Fleeing Vehicle

Elapsed Time ^a	20 mph ^b	35 mph ^b
10 min.	35 sq. mi. (2)	107 sq. mi. (5)
15 min.	79 sq. mi. (4)	240 sq. mi. (10)
20 min.	140 sq. mi. (6)	427 sq. mi. (17)
30 min.	707 sq. mi. (29)	962 sq. mi. (39)

^a Measured from when the vehicle starts moving (normally within five minutes after launch).

^b The number in parenthesis indicates how many LOCAAS are required to search the area assuming each munition covers a 25-sq. mi. area with no overlap.

Based on the above table, the size of the search area increases with the square of how far the vehicle travels during the elapsed time. Thus, while it only takes four LOCAAS to adequately search for a 20 mph vehicle at fifteen minutes (79 sq. mi.), it takes twenty-nine LOCAAS at thirty minutes (707 sq. mi.), over seven times the previous number. In addition, the search area continues to grow even after the LOCAAS arrives on station. For example, even if a LOCAAS arrives at ten minutes after a 20-mph vehicle departs, more than two LOCAAS are required because they cannot search the entire area instantaneously, and in ten more minutes, the search area has quadrupled in size. With

launch, the system provides estimates of launch point, intercept point, and impact point that can be data linked to other C2 platforms; Tom Grady, AFRL/MNG, interviewed by author, 19 November 2001.

¹²⁶ Mike Lukes and Eugene McKenzie, "Theatre Missile Defense (Attack Operations) for those Tactically Challenged," *Unpublished Concept Paper on Knowing Your Enemy*, 30 September 1997, 28.

¹²⁷ *Ibid.*, 33. A MAZ 543 SCUD TEL can travel at a maximum speed of 60 kph, or about 35 mph.

this in mind, it appears that for LOCAAS to be effective and cost efficient, they need to arrive at the launch site either before launch (if we can detect, locate, and identify it) or soon thereafter.

For LOCAAS to perform an area search for the target, the original glider design that was flight tested in the 1990s was scrapped, and a five-pound turbojet engine that produces thirty pounds of thrust was added.¹²⁸ With this addition, the LOCAAS can now fly about 200 mph for thirty minutes, or about one hundred miles in distance.¹²⁹ To give the LOCAAS enough time to search for its target, LOCAAS is air-delivered by either aircraft or missiles (such as a hypersonic delivery vehicle) within fifty miles of the target area where it will then cruise for fifteen minutes (or less) to reach the target's expected location. Upon reaching the location, LOCAAS will then spend the rest of its time searching the area for the target. With fifteen minutes of search time, the LOCAAS can cover about twenty-five sq. mi. of territory.¹³⁰ If the target is not found, the LOCAAS self-destructs so "the enemy cannot get its hands on the technology."¹³¹

To incorporate LOCAAS into its inventory, the USAF granted \$33 million to Lockheed Martin in December 1998 to build a prototype munition.¹³² Originally, the prototype munition was expected to fly by the end of 2003, but due to some successes, it now appears that LOCAAS's first flight will occur in 2002.¹³³ If the flight tests are

¹²⁸ Lance Cheung, "Mini-missile has mind of its own," *Airman Magazine*, March 2001, n.p., on-line, Internet, 14 October 2001, available from <http://proquest.umi.com>

¹²⁹ Glenn W. Goodman, Jr., "Tank Eradicators," *Armed Forces Journal*, August 2000, 38.

¹³⁰ Ibid.

¹³¹ Timothy P. Barela, "Anti-armor Einstein," *Airman Magazine*, September 1996, n.p., online, Internet, 07 April 2002, available from <http://www.af.mil/news/airman/0996/armor.htm>.

¹³² Sandra Erwin, "Technologists chasing mobile target hunters," *National Defense*, June 2000, n.p., on-line, Internet, 15 October 2001, available from <http://proquest.umi.com>.

¹³³ AFRL/MN, "ACC Applied Technology Council Meeting," briefing given on 31 October 2001; Christopher Bowie et al., *The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns*, RAND Report prepared for the US Air Force (Washington, D.C.: RAND, 1998), 16.

successful, the USAF plans to buy 12,000 of these munitions at a cost of about \$33,000 each.¹³⁴

Unlike most air-to-ground munitions that contain hundreds of pounds of explosives, LOCAAS utilizes a small multi-mode warhead not much bigger than a soup bowl. Because the warhead is small, LOCAAS is only thirty-one inches long and weighs a meager eighty-five pounds.¹³⁵ The warhead has three different modes of operation: fragmentation for a soft kill on soft vehicles, an aerostable slug for standoff, and a stretching rod for hard armor, and it is selected based on the type of target engaged.¹³⁶ The key enabler that allows LOCAAS to determine the type of target and then select the proper mode of kill is advanced ATR software.

To accurately detect and identify targets, LOCAAS utilizes LADAR in conjunction with advanced algorithms. Although LADAR has not been commonly used in the past, the technology is not new and has been used extensively in medical instruments and bar-code scanners.¹³⁷ In essence, LADAR works by emitting light and then capturing the returning image to form a three-dimensional (3D) image of the area. Once a picture is captured, advanced processing is done to scan the picture for potential targets. If a potential target is identified, it is compared to stored target templates in the ATR's software database. If a match occurs, the LOCAAS dives down upon its prey, selects the appropriate warhead mode based on the target type, and delivers the fatal

¹³⁴ Erwin, n.p.

¹³⁵ Goodman, 38.

¹³⁶ Hathaway, 50.

¹³⁷ Doug Richardson, "Casting light on a target," *Armada International*, June/July 1999, n.p., on-line. Internet, 16 October 2001, available from <http://proquest.umi.com>. One exception is the AGM-129A Advanced Cruise Missile (ACM) which uses LADAR for terminal guidance; Erwin, n.p.

blow.¹³⁸ Although seemingly simple, one problem with ATR technology is its inability to find and identify targets fully or partially hidden by foliage or other debris.¹³⁹

Since LADAR is light energy, it cannot adequately penetrate through foliage or other obscurations to detect targets. While there is little that can be done to alleviate this problem with fully obscured targets, the Defense Advanced Research Projects Agency (DARPA) is working on a solution for partially obscured targets. The program, called JIGSAW, attempts to solve the problem by taking several pictures of a potential target from different viewing angles, peering down through holes in the foliage and then fusing the data together.¹⁴⁰ The end result is an enhanced 3D image that increases the probability for successful target identification. Another problem with ATR technology is its lack of ability to discriminate between real targets and objects that look like targets.

This phenomenon, often called a systems constant false alarm rate (CFAR), is the rate at which a system misidentifies objects as targets.¹⁴¹ Because there are many naturally occurring objects that look like targets when viewed with LADAR, current versions of ATR programs have difficulty in discriminating real targets from look-alike targets, especially in cluttered terrain. Needless to say, probably few commanders will want to assume responsibility for a munition that cannot be trusted to kill only valid targets, especially since the political ramifications of fratricide or collateral damage are often unbearable. In essence, "all bombs are becoming political bombs, and air commanders must be aware of their emerging constraint - hundreds of millions of people

¹³⁸ Goodman, 38.

¹³⁹ Grady interview.

¹⁴⁰ "Jigsaw Project Concepts," DARPA Special Projects Office, n.p., on-line, Internet, 30 November 2001, available from <http://www.DARPA.mil/SPO/Solicitations/BAA01-15/JIGSAW-Concepts.htm>.

¹⁴¹ CFAR is normally associated with the rate of false target indications in a radar system, caused by interference or noise levels that exceed the established detection threshold.

will judge [via CNN] the appropriateness of everything an air commander does.”¹⁴² This aspect of warfare must be part of a commander’s decision process, and it may drive him to wage war through the delicate application of force instead of mass destruction to create shock and awe.

Two solutions are possible to increase an ATR program's ability to precisely identify targets. First, create a very stringent target template in the ATR algorithm so that an object is only declared a target when an exact match occurs between the template and the 3D image. The obvious drawback to this approach is the lack of efficiency. In this case, LOCAAS enjoys a one hundred percent assurance of its target, but many targets are bypassed because of match inadequacies. The result is a LOCAAS that seldom finds what is looking to kill, even when encountering valid targets. The other solution is to incorporate man-in-the-loop (MITL) guidance.

MITL guidance enables a human operator to view the target and then decide whether to engage it. This approach has two distinct advantages. First, it keeps the question of accountability solidly answered at all times. Second, MITL allows for increased flexibility and risk reduction. Because of these reasons, one study asserted that any LOCAAS-type autonomous weapon should incorporate a MITL capability.¹⁴³ Unfortunately, however, LOCAAS is not currently planned to utilize MITL guidance, mainly to limit the munition's cost.

LOCAAS's strength is its low cost and ease of integration. Estimated to cost \$33,000, each LOCAAS is roughly equivalent in cost to two JDAM. This fact assumes a

¹⁴² Phillip S. Meilinger, *10 Propositions Regarding Air Power*, (Air Force History and Museums Program, 1995) 46-47.

¹⁴³ Keith J. Kosan, "Precision Engagement Against Mobile Targets: Is Man In or Out?" (master's thesis, School of Advanced Aerospace Studies, June 2000), 84.

UCAV or manned aircraft as the delivery platform. The costs of using LOCAAS rapidly sky rockets when delivering them via expensive hypersonic or stealthy cruise missiles. Considering that an AGM-158 Joint Air to Surface Standoff Missile (JASSM) is projected to cost \$300,000 and carries only three LOCAAS, efficiency of operation quickly deteriorates.¹⁴⁴ In addition, while hypersonic vehicles are much faster than the JASSM, they are projected to cost \$200,000 and will carry only two LOCAAS.¹⁴⁵ Nevertheless, a faster delivery increases efficiency because the search area is decreased, resulting in fewer LOCAAS required to find, identify, and engage a moving target. In the end, it appears that in regard to cost effectiveness, delivering LOCAAS by reusable aircraft is the most efficient means, followed by hypersonic delivery, and, finally, JASSM.

Hypersonic Missiles

There are two advantages hypersonic missiles offer, decreased response time and survivability. Decreased response time is derived directly from the missile's speed. Most hypersonic missiles fly at speeds ranging from Mach 5 to Mach 8, which translates to about 50 to 80 miles per minute.¹⁴⁶ Considering that a supersonic Mach 1 aircraft covers about ten miles per minute or 50 miles in five minutes, a hypersonic missile traveling at Mach 8 can cover four hundred miles in the same time. The difference is staggering. In essence, hypersonic missiles enable them to be launched well outside any threat

¹⁴⁴ Federation of American Scientists, "AGM-158 Joint Air to Surface Standoff Missile," on-line, n.p., Internet, 28 November 2001, available from <http://www.fas.org/man/dod101/sys/smart/index.html>.

¹⁴⁵ Frank Fernandez, director, Defense Advanced Research Projects Agency, address to Subcommittee on Emerging Threats and Capabilities, Committee on Armed Services, United States Senate, Washington, D.C., 21 March 2001, 11.

¹⁴⁶ Kevin L. Zondervan, Senior Project Engineer for the Aerospace Corporation, interviewed by author, 13 December 2001.

envelopes and still impact the target with the same timeliness of an aircraft loitering close to the target.

Another advantage of hypersonic missiles is their survivability. Similar to the well-known Patriot system that is capable of engaging inbound missiles, the highly exported Soviet SA-10 Grumble can do the same. In fact, the SA-10 is very difficult to destroy even with HARM missiles because the SA-10 engages and shoots down the incoming missiles before they can reach the system's components. Other double-digit SAMs are equally difficult to engage. The benefit of a hypersonic missile is that enemy SAM systems cannot adequately engage them because they are travelling too fast for successful intercept. In sum, hypersonic missiles are very difficult to negate, and, because of this fact, are very useful in attacking targets protected by highly capable double-digit SAMs.

While hypersonic vehicles offer these two advantages, their development has been plagued by several technological problems. First, reliable engines are very expensive and difficult to manufacture.¹⁴⁷ Research into ramjets dates back over fifty years, but relatively few hypersonic vehicles have been developed because of the engine's inability to sustain adequate thrust to maintain hypersonic speeds.¹⁴⁸ Today, however, the supersonic combustion ramjet (scramjet) is being perfected and has propelled missiles above Mach 5 for long periods of time.¹⁴⁹ Unlike solid fuel engines that burn out quickly, long-burning scramjet engines allow for greater range and increased payloads.¹⁵⁰

¹⁴⁷ Grady interview.

¹⁴⁸ David G. Wiencek, "Hypersonics: A New Age Dawns," *Global-Defense Missile Systems Index*, on-line, Internet, 10 October 2001, available from http://www.global-defense.com/missiles/missile_core.html.

¹⁴⁹ "Hypersonic Scramjet Projectile Flies," *DARPA News Release*, 27 August 2001, n.p., on-line, Internet, 30 November 2001, available from www.DARPA.mil.

¹⁵⁰ Ibid.

The second problem plaguing hypersonic missile development is airframe heating. Aerothermic heating occurs by the friction of the air passing over the missile's body, and, at Mach 4, results in a temperature of about 1,200 degrees Fahrenheit. As the speed increases to Mach 6 and Mach 8, the temperature increases to a whopping 2,800 and 5,600 degrees Fahrenheit, respectively.¹⁵¹ While some materials such as titanium and Inconel material can handle temperatures in the Mach 4 range, the main problem is keeping the missile's internal payload (i.e., the warhead) cool so it does not explode.

Another technological problem incurred is fitting a warhead of adequate size into the slender body of a hypersonic missile.¹⁵² One proposed solution is to negate the warhead altogether and use the missile itself as a kinetic kill vehicle. Since kinetic energy varies directly with the square of the missile's velocity, a missile striking a target at Mach 8 generates sixty-four times the energy as the same missile striking the target at Mach 1. For this reason, hypersonic vehicles with inert, kinetic kill warheads are ideal for hardened or deeply buried targets such as C2 bunkers. While adequate for fixed targets, this approach is not suited to attack moving targets because the missile is not redirectable in flight. In essence, once the missile is launched, it attacks a predesignated fixed target. To overcome this limitation, LOCAAS is used.

To successfully eject LOCAAS munitions without injuring them, the hypersonic missile must slow to subsonic speed.¹⁵³ While this feat might seem simple, a slender missile body traveling at Mach 8 descending at a steep angle towards the earth has little desire to slow down on its own accord. Boeing recently explored nine different dispense concepts, but the follow-on program to test their viability went unfunded. Tom Grady, an

¹⁵¹ Correll, n.p.

¹⁵² Grady interview.

expert in the field, believes it will be an expensive proposition to get the dispense technology perfected by 2010, and it will likely result in decreased missile payload and more stability problems that will require even more effort to overcome.¹⁵⁴ At best, this is a difficult task, not to mention the need to self-destruct the expended hypersonic missile before it impacts the earth to minimize collateral damage.

To find solutions to some of these problems, several programs are currently in place, which include: the Affordable Rapid Response Missile Demonstrator (AARRMD), HyTech, the Low Cost Missile, and the High Speed Strike System (HiSSS). The first program, DARPA's AARRMD, is developing a \$200,000, Mach 6 to 8, rapid response missile that can engage TCTs or deeply buried hardened targets.¹⁵⁵ To propel the missile, DARPA is formulating a ramjet that burns hydrocarbon fuel and is capable of sustaining a missile at Mach 6 for six hundred miles with 250-pounds of payload.¹⁵⁶ Another hypersonic program is HyTech.

HyTech is a program initiated by the USAF in 1995 to design and test technologies for successful hypersonic flight of missiles, aircraft, and trans-atmospheric vehicles. The program is funded at about \$20 million per year and is currently concentrating on developing a scramjet propulsion system that will operate from Mach 4 to Mach 8. The program's focus is to develop an air-to-surface hypersonic missile that can travel 750-nm in less than twelve minutes.¹⁵⁷

The third hypersonic program is the Low Cost Missile, sometimes referred to as Fast Hawk. This missile has been in development since 1997 when Boeing received an

¹⁵³ Ibid.

¹⁵⁴ Grady Interview.

¹⁵⁵ Fernandez, 11.

¹⁵⁶ Wiencek, n.p.

\$8 million contract from the US Navy. The initial contract called for a 36-month program to develop and demonstrate hypersonic technologies for the Navy's next generation land-attack system.¹⁵⁸ One interesting feature of Fast Hawk is its wingless design. The missile changes direction by bending its airframe. The specifics on how the technology works are puzzling and outside the scope of this thesis. The last program that looks promising is the High Speed Strike System (HiSSS).

The HiSSS is sponsored by the Office of the Chief of Naval Operations (OPNAV) and sole purpose is to merge the new technologies developed in the aforementioned hypersonic programs to produce a common-use hypersonic missile by 2010.¹⁵⁹ The missile is expected to fly at Mach 3.5 to 7 for 600 nm. Currently, the HiSSS missile is not planned to carry LOCAAS or attack moving targets but will rely on a kinetic kill warhead that penetrates up to 36 feet of concrete. In order to obtain buy-in from the various services, the OPNAV wants the missile to be capable in all weather conditions, day or night, and employable from USAF strike platforms, Naval air, surface, and subsurface forces, and the Army's Multiple Launch Rocket System (MLRS).¹⁶⁰ Provided procurement proceeds as planned, the missile is slated to field in 2010 with the purchase of 1,200 missiles by 2015.¹⁶¹

UCAVs

Although perceived as a new technology, the development and use of unmanned air vehicles can be traced back to WWI with the production of the US Army's Kettering Bug. This unmanned aircraft traveled at 55 mph and carried a 180 pound bomb forty

¹⁵⁷ Ibid.

¹⁵⁸ Correll, n.p.

¹⁵⁹ Ibid.

¹⁶⁰ Ibid.

miles where it then nosed-over and crashed into the intended target.¹⁶² Since this genesis, however, unmanned aircraft development has been slow to progress because of technological deficiencies, political resistance, and lack of cooperation between services.¹⁶³ Even in times when an operational UCAV was greatly needed, spurring developmental programs into action, the programs were soon abandoned when the need subsided, mostly due to high program costs with minimal returns.¹⁶⁴ With the success of UAVs in Desert Storm, Bosnia, and Kosovo, however, the story has changed, and the USAF is now fully committed to developing and integrating UCAVs into their warfighting strategy.¹⁶⁵ In fact, Gen John Jumper recently stated, "We plan to pursue this [UCAV] program once the [advanced technology demonstrations] are over. I don't think there's any doubt about that...UCAVs will come, and we will work the concept of operations to include them."¹⁶⁶

To jumpstart the development of an operational UCAV, the X-45, the USAF and DARPA established a three-phased Advanced Technology Demonstration (ATD) program in October 1997. The first phase granted awards to four companies to provide competing designs that would meet the X-45's specifications. In March 1998, Boeing's Phantom Works won the competition, which prompted the beginning of phase 2. Phase 2 is 42 months long and should be completed by the end of FY2002. During this phase, development and demonstration of the X-45 will occur, validating the technology and its

¹⁶¹ Wiencek, n.p.

¹⁶² Steven M. Shaker and Alan R. Wise, *War Without Men* (N.Y.: Pergamon-Brassey's, 1988), 22.

¹⁶³ Richard M. Clark, *Uninhabited Combat Aerial Vehicles: Airpower by the People, For the People, But Not with the People*, (Maxwell AFB, Ala.: Air University Press, August 2000), 28-32.

¹⁶⁴ *Ibid.*, 32.

¹⁶⁵ Charles L. Barry and Elihu Zimet, "UCAVs - Technological, Policy, and Operational Challenges," *Defense Horizons*, October 2001, n.p., on-line, Internet, 06 February 2002, available from <http://www.ndu.edu/inss/DefHor/DH3/DH3.htm>.

feasibility.¹⁶⁷ The last phase culminates with the demonstration of a fully operational X-45B UCAV in FY2007. If the program proceeds as planned, operational UCAVs could be fielded by 2009.¹⁶⁸ As of 29 October 2001, the X-45A was undergoing taxi tests at Edwards AFB, California.¹⁶⁹

As currently designed, the X-45A is a stealthy, tailless, 10,000 pound aircraft that is about two-thirds the size of an F-16. Once loaded with fuel and ordnance, the X-45A tips the scales at 19,000 pounds and utilizes a Honeywell F124 Turbofan to propel it to operating altitudes above 40,000 feet at speeds in excess of Mach 0.8. Practically impossible to track with radar and operating at high altitudes where it cannot be engaged by optical AAA and SAM systems, these characteristics give the X-45 autonomy of operation. In fact, the only threats capable of shooting down a stealthy UCAV are enemy interceptors where the pilot visually acquires the UCAV and then employs heat-seeking missiles or bullets to engage it. While this is possible, experience has shown that the "Big Sky" theory makes it improbable.¹⁷⁰

One of the big advantages of the X-45 is its ability to carry diverse ordnance loads and incorporate MITL into its guidance. With two 168-inch weapon bays, the X-45 is capable of carrying four HARMS, twelve Small-Diameter Bombs (SDBs), twelve LOCAAS, two 1,000 pound JDAMs, or two Joint Standoff Weapons (JSOWs). Because the weapon bays are split, the X-45 can mix its munitions (e.g., one JDAM and six

¹⁶⁶ John A. Tirpak, "Send in the UCAVs," *Air Force Magazine* 84, no. 8 (August 2001), n.p., on-line, Internet, 05 December 2001, available from <http://www.afa.org/magazine/August2001/080lucav.html>.

¹⁶⁷ Hathaway, 53.

¹⁶⁸ Earl Wyatt, "DARPA/USAF UCAV: Accelerating UCAV Capability to the Field," *UCAV Brief*, 28 January 2002, slide 9.

¹⁶⁹ Robert Wall, "X-45A UCAV Poised for First Flight," *Aviation Week & Space Technology*, 29 October 2001, 97.

¹⁷⁰ The "Big Sky" theory asserts that because the atmosphere is so big and vast, there is little chance of two or more airplanes engaging each other from pure happenstance.

LOCAASs).¹⁷¹ The end result is a very flexible platform that is tailorable for a wide variety of applications.

The other big advantage is MITL guidance. As suggested earlier, MITL guidance allows for human interaction in the engagement process. The X-45 incorporates this guidance by utilizing a high-resolution SAR sensor that produces a target image that is relayed via data link back to the operator. Once the operator confirms the target, it is attacked. One additional benefit of the on-board SAR sensor is that the UCAV may be used in an ISR role to augment other sensors such as Predator and Global Hawk. Currently, however, the planned missions for UCAVs are dull, dangerous, and dirty.¹⁷²

Dull missions are those requiring long endurance such as reconnaissance and surveillance patrols. Dangerous missions are those where conventional manned aircraft face risk incommensurate with the gain or situations where the political environment does not warrant the possible loss or capture of an American pilot. Dirty missions result when biological or chemical contaminants are used. Commensurate with the idea of dangerous missions, the USAF has determined the first UCAVs will accomplish SEAD.

The USAF's choice is logical based on one study that evaluated UCAVs, manned aircraft, and a space-based option in regards to life-cycle cost, risk to human life, feasibility, and mission effectiveness to perform the SEAD mission. The study concluded that UCAVs were the best option of the three platforms investigated.¹⁷³ In

¹⁷¹ David A. Fulghum and Robert Wall, "Mini-Bombs Dominate U.S. Weapons Plans," *Aviation Week and Space Technology*, 25 September 2000, n.p., on-line, Internet, 13 October 2001, available from <http://proquest.umi.com>. The SDB is a 250-pound GPS-guided munition that is designed for use in the UCAV, F-22, and other air vehicles. Although not as big as other air-to-ground munitions, it promises to service 85% of the targets currently taken out with 2000 pound bombs by its extremely high accuracy - 95% of the SDBs will land within three meters of its intended target; The JSOW is a glide-munition that can carry a unitary warhead or submunitions.

¹⁷² Clark, 39.

¹⁷³ Hathaway, 70.

addition, since ACC has determined that the combat air forces will be deficient in SEAD in 2015, the UCAV may help alleviate the problem.¹⁷⁴ One area of concern, however, is the UCAVs lack of range.

The X-45 has a range radius of about 650 nm.¹⁷⁵ A 1997 RAND study specifically addressed needed range requirements for the next generation attack fighter. The study investigated several scenarios. One scenario considered Iran, Iraq, and North Korea as enemy theaters of operation and, using favorable bases, found that only 70 percent of the targets could be attacked with a 650-nm range radius aircraft.¹⁷⁶ When the range radius was decreased to 600 nm however, some AAR was required in both the Iran and Iraq theaters to reach 70 percent of the targets. Another scenario evaluated the same enemy states, but with less favorable basing.¹⁷⁷ In this case, either an 800 nm range radius aircraft or significant AAR was needed to hold the same percentage of targets (70%) at risk. The results of the study are disturbing because the X-45 is not currently projected to perform AAR, and with a range of only 650 nm, it appears that the X-45 may not be very useful in performing the missions that it was "designed" to accomplish. In essence, if the UCAV is best suited for dull, dangerous, and dirty missions, its range must allow it to penetrate deep into enemy territory and attack those targets where manned aircraft fear to tread or to loiter for long periods on patrol. It appears that if the UCAV is going to be adequately suited to perform these types of missions, some serious modifications need to be made.

¹⁷⁴ Clark, 47.

¹⁷⁵ Mark E. Garner, AFRL UCAV Program Manager, interviewed by the author, 13 December 2001.

¹⁷⁶ Donald Stevens et al., *The Next-Generation Attack Fighter: Affordability and Mission Needs* (Washington, D.C.: RAND, 1997), 24-29. Favorable bases are the closest existing military bases to the theater of operation.

¹⁷⁷ Ibid. Less favorable bases are existing bases safe from theater ballistic missile attack or from being overrun.

Even if the range modification was made, however, and even with the UCAV's advantages of reusability, invulnerability to attack, and incorporation of MITL guidance, the UCAV still has difficulty quickly engaging emerging targets. Since there are limits to how many UCAVs will be available to loiter while waiting for tasking, they will not be able to be every place at one time. So while they might be positioned in likely target areas, they still will not be able to respond quickly to targets emerging outside expected areas. In the end, UCAVs suffer from the same time and space problems that prevent traditional aircraft from achieving fast response times. Unfortunately, there is little that can be done to rectify the problem. One benefit the UCAV does enjoy over manned aircraft, however, is its relatively low cost of procurement and operation.

The UCAV is expected to cost about one-third that of a JSF, about \$10 million, and its operations and support costs are estimated at only 25 percent of a manned fighter unit.¹⁷⁸ The operations and support savings stem from the operators training in simulators vice flying real aircraft. In fact, few UCAVs will ever fly daily sorties since they are crated and stored in special boxes where they remain for up to ten years, or until needed. When the need arises, the UCAV is loaded onto a transport, delivered to its operating area, assembled, fueled, and ready to fly. Of course the UCAV can self-deploy if airlift is in short supply. While still in storage, software changes are made directly through the UCAV's box via a receptacle. This allows the programmer to access the UCAV's memory to change software without breaking open the sealed container. Since the UCAV's flight controls are powered entirely by electricity, leaking hydraulic fluid or

¹⁷⁸ Tony Tether, director, Defense Advanced Research Projects Agency, address to Subcommittee on Emerging Threats and Capabilities, Committee on Armed Services, United States House of Representatives, Washington, D.C., 26 June 2001, 15.

dry-rotting rubber seals are of no concern. In the end, the UCAV is a tidy and efficient platform that promises to deliver many advantages, but only if its range is extended.

AMSTE

AMSTE (Affordable Moving Surface Target Engagement) is a program recently awarded to Northrop Grumman Corporation and Raytheon Systems for \$23.3 million that seeks to develop a methodology to engage moving surface targets with long-range precision standoff weapons.¹⁷⁹ To achieve this, the program will network and integrate sensors and weapons together without expensive modification to existing and future planned systems.¹⁸⁰ AMSTE's methodology to engage TCTs is to track them with radar from standoff systems and then relay the track data (i.e., the target's location) directly to a precision-guided weapon in flight. In essence, instead of using an area search munition like LOCAAS to scan an expected target area, AMSTE updates the target's location continuously to the weapon, eliminating the need to search. Two recent tests have proven that the concept is feasible.

The first test occurred on 15 August 2001 when three MTI radars - an ASARS-II, a Global Hawk radar, and a test-bed radar - were used to generate a precise track of a target. The target's location was then relayed via data link to a modified Maverick missile. The missile, continuously updated to the target's position, scored a hit on the moving target.¹⁸¹ The other test occurred on 28 August 2001 when two MTI radars, a Joint-STARS and a surrogate radar, tracked a moving target and relayed its location to a

¹⁷⁹ Stephen Welby, "Networked Targeting Technology," *DARPA Special Projects Office*, n.p., on-line, Internet, 28 November 2001, available from <http://www.DARPA.mil>.

¹⁸⁰ Tether, 7.

¹⁸¹ "DARPA Demonstrates Affordable Moving Surface Target Engagement," *DARPA News Release*, 31 August 2001, n.p., on-line, Internet, 30 November 2001, available from www.DARPA.mil.

guided-glide weapon. This weapon also scored a hit.¹⁸² There are, however, limitations to the concept.

First, LOS obstructions are a concern. As discussed earlier, in order to see and track a vehicle, radar must have an unobstructed view of the vehicle. Targets in deep or rugged terrain pose particular difficulties since targets may only be seen intermittently as they weave in and out of culverts. Just when one thinks a valid track is obtained and a weapon is launched, there is no way to know when the target will soon disappear behind some intervening terrain, causing the radar to break lock and result in an unsuccessful engagement. While Global Hawk and manned aircraft minimize LOS obstructions by flying close to the AOI, standoff is greatly compromised. Space is perhaps the best platform for AMSTE to utilize, but it will not be fully operational until about 2020 and will need powerful target tracking radars because of the increased ranges involved.¹⁸³

Second, because accurately tracking moving vehicles demands high radar update rates, radars used with AMSTE will not likely be capable of performing other tasks when busy tracking a target. Considering that a limited number of radars are available to perform all of the ISR functions, dedicating even a few of these radars to AMSTE will most likely degrade the overall ISR effort.¹⁸⁴ And, if only a few radars are dedicated to AMSTE, the system will be capable of engaging only one target at a time. One solution is to time-share the radars between collection and engagement and this might offer a reasonable compromise provided it could be implemented.

The last limitation is the need for a vehicle to deliver the weapon. Most munitions other than cruise missiles and LOCAAS are delivered within ten miles of the

¹⁸² "DARPA Demonstrates Affordable Moving Surface Target Engagement," n.p.

¹⁸³ Corcoran, 2.

target. If an aircraft must come so close to deliver the munition, then why invest in AMSTE when the aircraft could use a maverick-type munition and perform the entire engagement on its own? Therefore, for AMSTE to have any value, it must use long-range weapons that are delivered from standoff orbits. Cruise missiles such as JASSM or hypersonic missiles will hardly prove cost efficient. One likely munition is the SDB with a bolt-on wing kit. This munition flies over thirty miles when dropped from high altitude, and since it is relatively inexpensive, it might provide a reasonable exchange between standoff and cost.¹⁸⁵

Chapter Summary

This chapter investigated and evaluated the USAF's proposed approach to eliminate bottlenecks in the kill chain. It was found that while ISR's capabilities in 2010 will be improved, discrepancies will still exist, specifically in areas outside sensor coverage. Many vehicles are being developed to engage TCTs, but all have limitations. LOCAAS is cheap, but unless its ATR feature is improved, it may be of little use with today's high concern for collateral damage. Hypersonic missiles offer great advantages in speed but cannot engage moving targets without either incorporating in-flight updates or delivering LOCAAS munitions. The UCAV is perhaps the best option, but it lacks the required range and speed of response to perform all of its dull, dangerous, and dirty missions as proposed. The last proposal, AMSTE, promises to overcome the need for a LOCAAS-type munition, but it will require many radars to engage even a few TCTs. In addition, radar LOS problems are still incurred with AMSTE's long standoff distances, and some type of cheap munition such as the SDB with wing kit will need to be used.

¹⁸⁴ Grady Interview.

¹⁸⁵ Fulghum and Wall, n.p.

Chapter 4 proposes that perhaps there is a better approach to solving the problems associated with TCTs.

Chapter 4

The Preemptive Approach

Opponents will take advantage of delays or shortcomings in US quick reaction targeting capabilities to shelter threat systems. Therefore, Future Battlespace Dominance requires the ability to hold opposing forces at risk any time, in any weather, stationary, or moving.

— Stephen Welby
DARPA Special Projects Office

This chapter investigates the feasibility of using a preemptive approach for engaging TCTs and begins by defining the approach with the introduction of its associated kill chain. After this, future methods of accomplishment are investigated to include both ground mines and the Low Cost Persistent Area Dominance (LOCPAD) Miniature Munition. The chapter concludes with a summary of its findings.

Defining the Approach

Unlike the reactive approach that speeds through the kill chain after detecting a TCT, the preemptive approach uses intelligence to predict where the enemy will act and then employs persistent aircraft or weapons to patrol the area. As soon as the aircraft or weapon detects a COI, it is located, identified, destroyed, and assessed in one fell swoop. In essence, the bulk of the traditional kill chain's process is consolidated and integrated into the aircraft or weapon loitering over the target area. Figure 2 displays the kill chain in two levels: (1) predictive measures and (2) integrated ISR weapons systems.

Level 1 – Predictive Measures

The primary enabler of preemptive employment is having the means to predict the enemy's location. Since it is unlikely that a commander will ever have perfect

intelligence to accurately predict where a TCT will emerge in all cases, the question of using aircraft or weapons in a preemptive role relies on the commander's willingness to take some degree of risk. While there is no question that tasking aircraft or munitions to loiter over unproductive territory is inefficient and wasteful, if some degree of probability exists that a TCT is in the area, the payoff may be worth the risk. The payoff is determined by the value gained by destroying the TCT and is calculated by the threat it imposes on friendly forces. For example, if enemy SCUD missiles are known to carry nuclear, biological, or chemical (NBC) warheads, a commander may likely risk wasting some of his resources to ensure the missiles are located and destroyed before they can be launched against friendly forces. In this situation, a commander will most likely opt to preemptively employ forces even with a poor intelligence estimate of the SCUD's location.

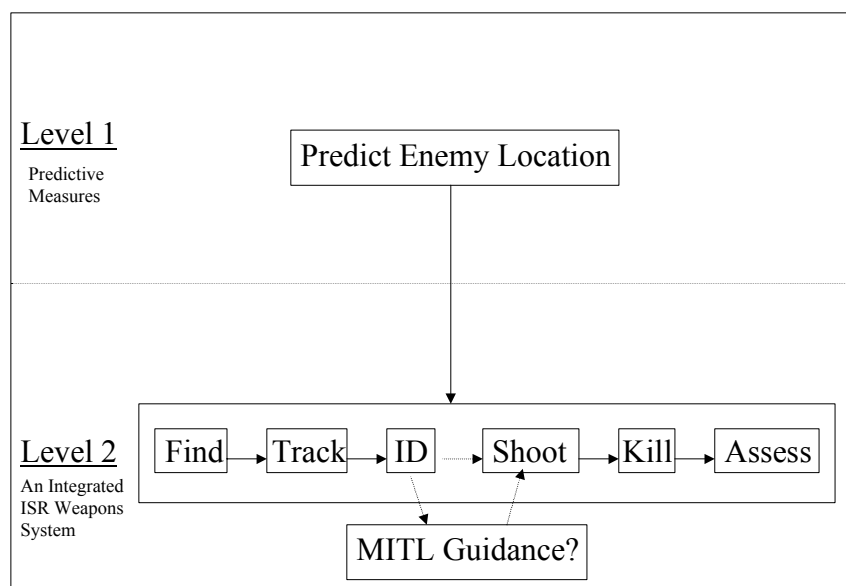


Figure 2 - The Preemptive Kill Chain

This fact was evidenced in Desert Storm when General Horner dedicated over 4,700 sorties to preemptively hunt for SCUDs.¹⁸⁶ Part of the effort used A-10's to "scour the roads that mobile SCUDs were likely to travel from their storage areas to launch sites."¹⁸⁷ At night, AC-130's patrolled expected SCUD operating areas in hopes of scoring a kill. In addition, since planners knew the ranges of the SCUD missiles and their potential targets like Tel Aviv, Riyadh, or Dhahran, they were able to predict SCUD launch areas. Once the areas were identified, F-15E's flew combat air patrols (CAPs) directly over these launch areas in an effort to find and destroy the SCUDs.¹⁸⁸ In all of these cases, General Horner did not wait to detect a SCUD before utilizing his forces. Instead, he preemptively employed forces based on intelligence prediction to seek out and kill them. While General Horner's approach might have been inefficient, the political ramifications of Iraqi SCUDs landing in Israel mandated the effort.¹⁸⁹ Gen John Jumper wants to further General Horner's approach of limiting TCT search areas by analyzing terrain features, he states, "If you provide rules such that tanks can't sit on the sides of cliffs and SA-3's can't be on mountain peaks, you quickly take away sixty percent of the terrain that is of consequence to any maneuver on the battlefield."¹⁹⁰ While General Jumper's suggestion may vary based on the battlefield's topography, his approach will reduce the needed search requirements based on fewer possible enemy locations.

¹⁸⁶ Kevin L. Fox, "Dynamic Targeting: Are We Ready?" (master's thesis, Air Command and Staff College, April 1999), 41.

¹⁸⁷ Perry D. Jamieson, *Lucrative Targets: The U.S. Air Force in the Kuwaiti Theater of Operations*, (Washington, D.C.: U.S. Government Printing Office, 2001), 50.

¹⁸⁸ Ibid.

¹⁸⁹ Ibid., 49.

¹⁹⁰ Gen John P. Jumper, chief of staff, US Air Force, address to the AFA's 17th Annual Air Warfare Symposium, Orlando, Florida, 15 February 2001.

Another factor that influences the amount of risk a commander will accept is cost and relates directly to the number of excess aircraft or munitions available for use. Commanders who harness an overabundance of aircraft or munitions can likely afford to squander some assets. But, an overabundance of assets is seldom the case. Instead, most commanders are limited in resources and do not have all the aircraft, space platforms, or munitions they desire. This fact is especially true for high-tech weaponry like stealth aircraft and precision-guided munitions (PGMs). One example that proves this point recently occurred in Operation Enduring Freedom (OEF) where limited stockpiles and production of JDAMs led to a serious shortage. The coalition was using about forty JDAMs per day but only forty were being produced each month. Hence, the shortage became extreme in only a few months and the commander had no choice but to slow down JDAM expenditure.¹⁹¹ A similar problem occurred in both the Gulf War and Bosnia when the limited production and development of cruise missiles could not keep pace with requirements.¹⁹² Although greater stockpiles and better procurement strategies could ensure more stocks on hand, shortages in assets will likely continue. Thus, better prediction is critical to help increase efficiency and minimize wasting resources. One concept that promises to increase successful prediction is an intelligence concept called Predictive Battlespace Awareness (PBA).

PBA is the process of analyzing enemy activities to the point where they can be accurately predicted.¹⁹³ To accurately predict the enemy's actions, however, one must first understand the enemy. To do this, intelligence must be collected, analyzed, and then

¹⁹¹ Maj David Hathaway, CENTAF's Chief of Strategy, interviewed by the author, 30 Nov 01.

¹⁹² Glenn Buchan, "Information War and the Air Force: Wave of the Future? Current Fad?" *RAND Research Brief, IP-149*, (Washington, D.C.: RAND, March 1996), 2.

studied continuously. General Jumper states, “We [the USAF] collect and we observe and we have a very nice info briefing about this, but who’s the person out there who’s pulling that information out of the system, studying it down to the most minute detail, and figuring out how to go after that thing, and finding out what the most vulnerable point is, or part is, and figuring out how to keep that SA-10 from getting where it’s supposed to be? Who’s doing it? We don’t do that.”¹⁹⁴ General Jumper has a point. If one is to understand the enemy, one must not only gather information but also analyze it to gain understanding. Unfortunately, since the bulk of the information is collected with reconnaissance platforms that sporadically observe the enemy, only a few pieces of information are obtained at a time, making it very difficult to later combine all of the pieces over a continuum and gain the understanding General Jumper desires. One way to relieve this difficulty is to use surveillance.

Surveillance is the “systematic observation of aerospace, surface, or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means.”¹⁹⁵ In essence, while reconnaissance takes snapshots of enemy activity through time, surveillance watches the enemy systematically (i.e., continuously) and observes movement and processes. Because of this fact, greater insight into the enemy’s mind is gained that helps solidify the foundation for accurate prediction. Simply stated, close and continuous observation of enemy behavioral patterns leads to understanding, and understanding is the key enabler of prediction. Unfortunately, surveillance is difficult to achieve with air and space platforms.

¹⁹³ David A. Fulghum, "New Air Force Recce Aircraft Takes Shape," *Aviation Week & Space Technology*, 26 November 2001, 34.

¹⁹⁴ Jumper, address to the National Defense Industry Association Breakfast, Langley AFB, Va. 27 June 2001.

Surveillance requires persistent observation and necessitates that a sensor remain over an area for a long period of time. Since most satellites are over an area for only short periods at a time, surveillance is usually not possible from space.¹⁹⁶ Furthermore, while manned aircraft could provide surveillance in permissive environments, they usually suffer from fuel limitations and the threat of enemy air defenses.¹⁹⁷ Consequently, the result is that the majority of USAF ISR platforms provide reconnaissance with but a few (like SIGINT satellites in geosynchronous orbits) doing surveillance. To overcome this limitation, ground-based intelligence sources like Special Operations Forces (SOF), spies, or unattended ground sensors are used.

To conduct surveillance operations, SOF are normally inserted deep behind enemy lines where they secretly observe enemy actions. In Desert Storm, SOF used dune buggies inserted deep into Iraq to conduct SCUD missile surveillance. To remain covert, the dune buggies were specially designed to fold-up so they could be hidden during the day.¹⁹⁸ After the war, SOF reported destroying seven SCUDs and called in air strikes on five more to claim a total of twelve kills.¹⁹⁹ Although their claims were unsubstantiated and disdained by American intelligence sources, it is undisputed that SOF surveillance did contribute to the overall SCUD hunting campaign. One factor that limits SOF ability to conduct surveillance in populated or secure enemy areas is their need to remain hidden.

¹⁹⁵ Joint Publication 1-02, *DOD Dictionary of Military and Associated Terms*, 12 April 2001, 413.

¹⁹⁶ One exception is SIGINT satellites located in geosynchronous orbits.

¹⁹⁷ This was evidenced when Gary Powers was shot down in his U-2 over the Soviet Union by a SA-2 Guideline missile.

¹⁹⁸ Michael R. Gordon and General Bernard E. Trainor, *The General's War* (New York, N.Y.: Little, Brown and Company, 1995), 245.

¹⁹⁹ Ibid.

Spies overcome the SOF's limitation by infiltrating an enemy's organization and then attempting to gain access to sensitive information. Because spies work undercover, they can oftentimes provide information about the enemy's future intentions, grand scheme of maneuver, and centers of gravity (COGs). The difficulty spies face, however, is transmitting or passing the information to outside agencies before the information perishes. Working inside the enemy's camp, spies cannot reveal their true allegiance and may have to wait inordinate lengths of time before passing the information. When this occurs, the value of the intelligence is degraded and may be of little use. One method used in the past to alleviate problems incurred with SOF and spies was to use unattended ground sensors.

Unattended ground sensors are airdropped devices that measure acoustic, seismic, magnetic, radio frequency, EO, or chemical emissions.²⁰⁰ In Vietnam, Igloo White used seismic, acoustic, and radio frequency unattended ground sensors to detect movement of vehicles and men on the Ho Chi Minh Trail. When one of the sensors detected movement, it sent a code to an orbiting EC-121 aircraft that relayed the information to the Infiltration Surveillance Center (ISC). The ISC correlated the code to the sensor's location and then contacted ABCCC to request an air strike. While there were problems with some sensors malfunctioning, Igloo White was credited with the real-time location of more than twenty percent of the attacked targets. Moreover, almost thirty-eight percent of the truck parks and fifteen percent of the trucks attacked were located with Igloo White.²⁰¹

With the success of Igloo White in Vietnam, the Remote Battlefield Acoustic and Seismic System (REMBASS) was developed in the late 1970s and uses acoustic, seismic, and magnetic sensors to detect and classify targets.²⁰² The system classifies targets into four broad categories that include personnel, wheeled vehicles, tracked vehicles, and unknown. Like its Vietnam era predecessor, the system transmits its findings to a central facility where the information is analyzed.²⁰³ In 1982, the improved REMBASS (I-REMBASS) was fielded and, other than offering a few slight enhancements in a smaller device, was not significantly modified from its original version.²⁰⁴ In the end,

²⁰⁰ Alan Vick et al., *Enhancing Air Power's Contribution Against Light Infantry Targets*, RAND, Project Air Force, (Washington, D.C.: RAND, 1996), 26.

²⁰¹ Ibid., 27.

²⁰² Nino Srour, "Unattended Ground Sensors: A Prospective for Operational Needs and Requirements," NATO Land Group 6, October 1999, online, Internet, 20 March 2002, available from <http://www.arl.army.mil/acoustics/ugs%20for%20nato%20land%20panel%206.pdf>, 4.

²⁰³ Since the monitoring device is mobile, this facility can be located in the field, even at the platoon level.

²⁰⁴ Federation of American Scientists, "AN/GSQ-187 REMBASS," on-line, n.p., Internet, 02 May 2002, available from <http://www.fas.org/man/dod-101/sys/land/rembass.htm>.

REMBASS and I-REMBASS were primarily designed to help SOF conduct surveillance or to allow division, brigade, and battalion army commanders track enemy movement beyond the forward line of troops (FLOT). One disadvantage of both REMBASS systems, however, is the need for them to be hand placed, and, because of this fact, special REMBASS teams are required to infiltrate hostile territory, place the sensors, and then evade back out.²⁰⁵ One future system that promises to overcome this limitation is the Internetted Unattended Ground Sensor (IUGS).

The IUGS system is deliverable by either aircraft or artillery and employs GPS along with acoustic, magnetic, seismic, environmental, and chemical sensors to detect enemy movement.²⁰⁶ Advances in digital signal processing and smaller computer chips have enabled the technology and result in a more robust and reliable system. Since the system is internetted, it is expected to enhance the Army's Future Combat Systems (FCS) program.²⁰⁷ Because IUGS decreases delivery difficulties and corrects many of the traditional problems of unattended ground sensors like high false alarm rates and power failures, IUGS will likely be more influential in providing surveillance than the other previously used ground sensors.²⁰⁸

In summary, successful prediction is very difficult but may be achievable by knowing the enemy's equipment capabilities, terrain delimitation, and surveillance. While all three methods should be used, surveillance is the best means to gain an

²⁰⁵ William T. Beckman, "Intelligence Scouts: REMBASS and Battlefield Surveillance," *Joint Readiness Training Center*, Newsletter 01-15, n.p., on-line, Internet, 02 May 2002, available from <http://call.army.mil/products/newsltrs/01-15/01-15ch6.htm>.

²⁰⁶ Vick, 17.

²⁰⁷ Tony Tether, director, Defense Advanced Research Projects Agency, address to Subcommittee on Emerging Threats and Capabilities, Committee on Armed Services, United States House of Representatives, Washington, D.C., 26 June 2001, 16. The FCS program is a collaboration of mobile, networked, command and control communications, autonomous robotic systems, precision indirect fires, air and ground organic sensors, and ISR capabilities that will enable and support future Army forces.

understanding of the enemy because it continuously monitors enemy action and provides minute detail about the enemy's behavior. Unfortunately, most air and space assets are not very adept at surveillance because they lack persistence. Ground-based sensors like SOF, spies, and unattended ground sensors help to overcome the problem of persistence and have been used successfully in the past. In the end, it appears that predicting the enemy's TCT locations may be possible to some degree in the future. Nevertheless, since it is unlikely to be perfect, the JFACC will still need to weigh expected benefits and risks to determine whether preemptive employment is a viable option.

Level 2 – Integrated ISR Weapons Systems

The preemptive kill chain's second level requires a loitering integrated ISR weapons system that can detect, locate, identify, shoot, kill, and assess a target. Because the integrated platform performs the majority of functions found in the traditional kill chain, attack is possible immediately after a COI is detected and identified. In the past, both manned aircraft and the Predator UAV have accomplished this task.

In Vietnam, FACs were used to find targets and then direct strike aircraft to attack them. But, when the enemy discovered FACs circling overhead, they quickly disappeared beneath the jungle canopy before strike aircraft could arrive and deliver their ordnance. One study found that in a four-month period during 1970, fifty-four percent of fleeting targets were not struck because firepower was not available.²⁰⁹ To overcome this difficulty, FACs began carrying ordnance that allowed them to attack a target as soon as it was identified. The OV-10, one of the first aircraft designed for this specific purpose,

²⁰⁸ Nino Srour, 4.

²⁰⁹ Benjamin Franklin Cooling, ed., *Case Studies in the Development of Close Air Support* (Washington, D.C.: Office of Air Force History, 1990), 437-438.

carried machine guns and four rocket pods.²¹⁰ With the integration of weapons and surveillance platforms the entire kill chain could now be accomplished with only one aircraft, and consequently, opportunities to kill elusive targets were no longer lost.

A similar situation occurred twenty years later in Desert Storm that rekindled the concept. Because Iraq's armor was dug-in and difficult to distinguish from decoys by traditional ISR methods, General Horner adopted the Killer Scout concept that sent pairs of F-16's into designated kill boxes to locate and destroy targets of opportunity.²¹¹ By tasking the same pilots to conduct the operation each day, a pilot could readily detect any changes on the ground and then either attack the target or mark it for another fighter to attack. Through systematic observation, the Killer Scouts achieved a level of surveillance that led one F-16 veteran assigned to the operation to say, "The Iraqis could not make a move without the Killer Scouts knowing about it."²¹² After the war, General Horner praised the Killer Scout effort, stating, "They [Killer Scouts] kept pressure on Saddam during the daytime. He could not move his forces. He just had to sit there and absorb punishment during the daytime."²¹³ In this example, prediction determined the kill box locations, and once the Killer Scouts arrived therein, the kill chain was quickly completed with little or no help from other platforms.

While the above examples demonstrate the effectiveness of the preemptive method using manned aircraft, certain contextual elements allowed manned aircraft to succeed. Traditionally, manned strike aircraft lack persistence and require support aircraft to accompany them into hostile airspace. In the examples presented, however,

²¹⁰ Ibid., 546.

²¹¹ A kill box was one-half degree latitude by one-half degree longitude, or about thirty miles on each side.

²¹² Jamieson, 75-76.

²¹³ Ibid., 78.

manned aircraft enjoyed autonomous operations because the majority of enemy air defenses were negated. In addition, enough assets were available to replace low-fuel aircraft loitering over an area with others, gaining a degree of persistence over the area. While history has shown that these contextual elements do occur, many other historical examples (some referred to in earlier chapters) provide evidence where they have not. Because of this fact, one should not view using manned aircraft for preemptive employment as a panacea, but only where favorable circumstances are present. Another air vehicle used as an integrated ISR weapons system is the Predator carrying Hellfire missiles.

The Predator UAV was modified to carry Hellfire missiles because of lessons learned in Kosovo. Similar to the experiences found in Vietnam and Desert Storm, targets detected often disappeared before strike aircraft could arrive and attack them.²¹⁴ To solve this problem, the USAF redesigned and strengthened the Predator's wings to carry two Hellfire-C laser-guided anti-tank missiles. With the modifications complete in February 2001, the USAF tested the innovation and successfully scored several hits on stationary tanks.²¹⁵ Currently, the armed Predator is being used in Afghanistan to attack emerging targets.²¹⁶ While the Predator's attacks have been successful in some respects, the Predator's poor accuracy and limited carriage capacity have hindered the effort.²¹⁷

Evidence in OEF has shown the Predator's ability to hit small objects is quite poor. Many times after a Predator missed its target, such as a vehicle carrying Taliban

²¹⁴ "RQ-1 Predator," *Federation of American Scientists*, n.p., on-line, Internet, 28 November 2001, available from <http://www.fas.org/irp/program/collect/predator.htm>.

²¹⁵ "Innovative Acquisition Approaches Lessons Learned from the HAE UAV Program," *RAND Research Brief*, (Washington, D.C.: RAND, 1999), 2.

²¹⁶ John Barry, "A New Breed of Soldier," *Newsweek International*, 10 December 2001, n.p., on-line, Internet, 04 December 2001, available from <http://www.msnbc.com/news/666232.asp?pne=msn>.

²¹⁷ Hathaway interview.

soldiers, the vehicle would stop and its occupants would get out and run away.²¹⁸ Since the Hellfire has little capability to target personnel in the open, once this happened little could be done to rectify the situation. On other occasions when the Hellfire did hit its intended target, very little damage was done because the missile's small, shaped-charge warhead lacked the required blast and fragmentation to kill the vehicle and its occupants.²¹⁹ The second limitation is the number of Hellfire missiles carried by the Predator. With a loiter capability of over twenty-four hours, two missiles do not provide much firepower, and once expended, the Predator reverts to an ISR asset without the capability to complete the kill chain autonomously. Furthermore, since reloading the Predator quickly is seldom an option because of the time it needs to return to base and then redeploy, there is little that can be done to rectify the problem. Because of all of these reasons, the Predator is not a viable integrated ISR weapons system.

Future Methods

Because manned aircraft and the Predator are inept in serving as integrated ISR weapons systems, other platforms with better capabilities are needed. The two candidates for consideration are ground mines and the LOCPAD Miniature Munition.

Ground Mines

While ground mines are not normally thought of as integrated ISR weapons systems, because they can detect, classify, locate, and then attack enemy targets, ground mines do qualify for consideration. In addition, since ground mines simply sit on the ground and wait, they offer levels of persistence that airborne platforms cannot offer. For these reasons, ground mines will be investigated. Since Gator mines are the only deep-

²¹⁸ Ibid.

attack mines that will be available in 2010, they will be the focus of consideration. Another system, the Army's Block II (Ultimate) Raptor, is expected to become operational around FY2011, but it will not be discussed for two reasons.²²⁰ First, it will not become operational in time to meet the needed requirements. Second, upon initial analysis, the Raptor system does not appear to offer many advantages over Gator.²²¹ So while the Raptor system is more technologically advanced and capable in some respects, an in-depth analysis is not warranted.

Gator Mine

Gator mine, sometimes referred to as CBU-89, is a 1,000-pound cluster munition that can be delivered by practically any of today's fighter or bomber aircraft. The cluster munition contains 72 anti-tank (AT) and 22 anti-personnel (AP) mines that are housed inside a casing called a Tactical Munitions Dispenser (TMD).²²² When dropped from an aircraft, the TMD falls ballistically until it senses a certain height above the ground where it then blows apart and dispenses the mines.²²³ On average, the mines in each TMD will cover an area of about 200 X 650 meters.

²¹⁹ "AGM-114 Hellfire," *Federation of American Scientists*, n.p., on-line, Internet, 18 February 2002, available from <http://www.fas.org/man/dod-101/sys/missile/agm-114.htm>.

²²⁰ The Raptor system is composed of the Hornet Wide Area Munition (WAM) and a sophisticated array of sensors and communications. When it detects a target inside 100 meters, the Hornet fires a sublet over the vehicle where it detonates, explodes, and sends a molten slug into the vehicle. The operator, usually located at a remote site, can control how a constellation of Hornets engages its prey. But, since the Hornet can only classify vehicles, not identify them, the operator's decisions are based on very rudimentary information. The system was originally devised to stop the invasion of Europe by the Russian hordes.

²²¹ This statement centers exclusively on engaging elusive vehicles deep in enemy territory. The author realizes the Raptor system offers many capabilities that Gator does not, but in regard to the limitations of land mines in general (i.e., spatial concerns and area coverage), a commander employing the Raptor system is faced with many of the same dilemmas as with Gator.

²²² "CBU-89 Gator Mine," *Federation of American Scientists*, n.p., on-line, Internet, 08 May 2002, available from <http://www.fas.org/man/dod-101/sys/dumb/cbu-89.htm>. The Navy's version of Gator is designated CBU-78 and weighs 490 pounds. Each canister carries 45 anti-tank and 15 anti-personnel mines.

²²³ The height is predetermined based on the desired density of mines to cover an area. The higher the TMD opens, the mine density becomes less because of increased mine dispersion.

Once deployed, the 22 AP mines deploy trip wires that, when disturbed, detonate the mine and send high-velocity shrapnel into the horizontal plane, serving not only to injure enemy personnel traversing the area, but also to protect the minefield from being cleared. The other 72 AT mines are specifically designed to kill armor. They consist of microelectronics that detect targets, discriminate armored vehicles, and then detonates an explosive charge into the belly of the vehicle once it is over the mine.

One of the advantages that Gator offers over other types of land mines is its ability to self-destruct at a predetermined time. Users can select from one of three options, which include intervals of 4 or 48 hours and 15 days, and this feature was designed to allow friendly forces to traverse the area later without the need for mine clearing equipment. Unfortunately, operational use has proven that the self-destruct mechanism is not one hundred percent reliable, so mine-clearing equipment is still needed (or at least recommended) for friendly forces to cross predisposed Gator minefields.²²⁴

Scatter mines like Gator were first used by US forces in Desert Storm.²²⁵ Here, they were used to deny Iraqi forces access to airfields and to create choke points along main roads. This fact was evidenced on 27 February 1991 when B-52 bombers scattered Gator mines along the Rumayla bridge, helping to prevent the escape of Iraqi forces before they could be attacked by coalition aircraft.²²⁶ The mines were also used extensively to target areas where SCUD TELs were likely to be operating. Such areas included culverts, overpasses, bridges, and staging areas. Based on the Gulf War Air

²²⁴ "Landmines in the 1991 Gulf War: A Survey and Assessment," *The Dupuy Institute*, n.p., on-line, Internet, 5 May 2002, available from <http://www.dupuyinstitute.org/pdf/m-4minesgulwar.pdf>.

²²⁵ Ibid.

Power Survey (GWAPS), however, these efforts only served to discourage road movement, and did very little to actually destroy the SCUDs or prevent them from launching missiles.²²⁷

The two primary reasons why the Gator mine was not effective in engaging SCUD TELs are: (1) the SCUDs dispersed months before the war began, and (2) the MAZ-543 SCUD vehicle travels off-road and can operate in a variety of environments. According to the GWAPS, the majority of SCUD TELs dispersed from their central bases by the end of August 1990, some four months before Desert Storm was initiated.²²⁸ Because of this fact, once the war started the SCUDs were already in hiding, and with so many places to hide, they were practically impossible to find. In addition, Iraqi SCUDs did not follow Soviet doctrine as coalition forces had expected, introducing even more fog and friction into the calculus. With these facts, it becomes clear that while Gator was used on expected SCUD operating locations, one could not possibly mine all of the areas. The lesson is that while Gator is useful for preventing or discouraging movement, if enemy vehicles do not have to move, then Gator is of little value. Such was the case with the Iraqi SCUDs.

Secondly, on those occasions when the SCUDs did move to either shoot or regenerate, they did not have to travel on primary road surfaces. The MAZ-543 SCUD transport vehicle incorporates an eight-wheel drive chassis with a 525 horsepower diesel engine, which easily traverses unprepared surfaces.²²⁹ With this capability, SCUDs tend

²²⁶ Eliot A. Cohen, *Gulf War Air Power Survey*, Volume II, Part II (Washington, D.C.: US Government Printing Office, 1993), 178.

²²⁷ Eliot A. Cohen, *Gulf War Air Power Survey*, Volume IV (Washington, D.C.: US Government Printing Office, 1993), 291-292.

²²⁸ Cohen, *Gulf War Air Power Survey*, Volume II, Part II, 333.

²²⁹ Mike Lukes and Eugene McKenzie, "Theatre Missile Defense (Attack Operations) for those Tactically Challenged," *Unpublished Concept Paper on Knowing Your Enemy*, 30 September 1997, 27, 32, 33.

to travel on secondary, tertiary, or even primitive roads located away from primary lines of communication. Since it is very difficult to effectively mine obscure areas where few if any natural choke points occur, employing Gator mines to stop SCUD operations are difficult at best.

Because of recent developments in the political scene, Gator mines may not be used regardless of their military effectiveness. In May 1997, President Bill Clinton pledged that the United States would sign the Ottawa Mine Ban Treaty that outlaws the use, production, stockpiling, and transfer of AP landmines. Even though the US hoped that Gator mines would escape the treaty because of their self-destruct mechanism, the other signatories disagreed stating that the self-destruct mechanism was unreliable. Thus far, the treaty has been signed by 140 nations, and while the US is the only NATO country that has not condemned the use of AP mines, the US plans to join the treaty and ban AP mines by 2006 if alternative weapons are adopted. Considering that some experts are already touting that alternative weapons exist, the ban may become a reality much sooner.²³⁰

Moreover, the political pressure to prevent fratricide and collateral damage may also prevent the use of Gator. Experience in Desert Storm showed that coalition ground forces sometimes stumbled unknowingly into Gator mines. Because pilots sometimes missed their targets, Gator ended up in locations unexpected by ground forces and hindered their movement. Consequently, when Gator was considered for use in Operation

²³⁰ "Vietnam Veterans of America Foundation Urges President Bush to Ban Landmines Immediately," *Vietnam Veterans of America Foundation*, 25 February 2002, n.p., on-line, Internet, 02 May 2002, available from http://www.vvaf.org/media/pr_022502.shtml.

Deliberate Force, its was quickly abandoned so as to prevent fratricide and collateral damage.²³¹

In the end, Gator has value in situations where the enemy is committed to movement along well-known lines of communication. Since TCTs are elusive, disperse early into hiding, and then traverse unprepared surfaces, engaging them with Gator is difficult. In addition, when considering that their future use will likely be banned, or at least restricted by political pressure, Gator does not offer a reasonable solution to the problem.

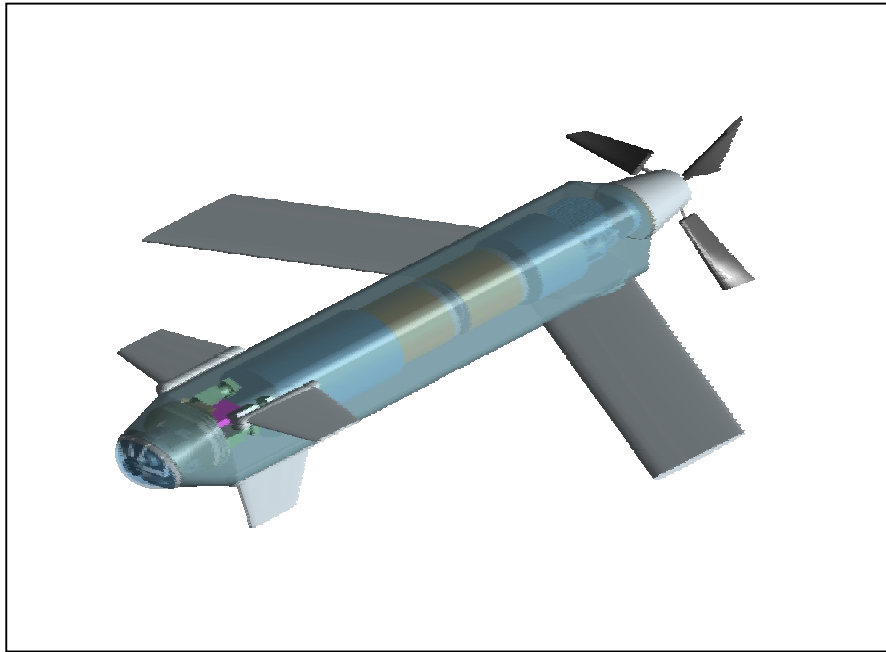
The LOCPAD Miniature Munition

Because manned aircraft, the Predator, and ground mines all have significant limitations in providing the USAF with an integrated ISR weapons system that can effectively engage TCTs, another platform with better capabilities is needed. To do this, personnel at AFRL's Armament Product Directorate conceptualized the LOCPAD, and with sufficient funding, it could be operational by 2009.²³² The LOCPAD (shown in Figure 3) is specifically designed for preemptive targeting and holds targets within a defined area at risk for long periods of time. Because each LOCPAD can only search a small area (i.e., NFOV search), multitudes of LOCPADs are needed to cover larger areas. In addition, LOCPADs must achieve an adequate revisit rate over the search area so that if a target emerges, it is detected and destroyed before it can escape the area or engage friendly forces. To achieve these ends, LOCPAD has a long-loiter capability, incorporates an ISR suite to detect, locate, and identify targets with either MITL guidance

²³¹ "Descriptions of Cluster Bomb Types," *Human Watch Rights*, n.p., on-line, Internet, 08 May 2002, available from http://www.org/reports/1999/nato2/nato995-04.htm#p221_47948.

²³² Gregory Jenkins, "Low Cost Persistent Area Dominance (LOCPAD) Miniature Missile," Concept Paper, (Eglin AFB, Fla.: Air Armament Enterprise, 2001), 4.

or ATR algorithms, integrates weapons that can destroy a variety of vehicles, and uses a full duplex data link architecture that allows for communication and control.



Source: USAF Armament Product Directorate
Figure 3. LOCPAD Design

Using a light, composite six-inch treated fuselage, low-drag wings, and a small gasoline engine, the LOCPAD is capable of flying for over twelve hours before exhausting its fuel supply.²³³ The LOCPAD's long-loiter capability is primarily achieved by an engine-propeller combination that is much more efficient than miniature jet turbines like those used in LOCAAS, sometimes by as much as eight fold.²³⁴ The tradeoff for efficiency, however, is speed. The LOCPAD travels at about seventy knots, and, although it can fly over long distances to its designated search area, the LOCPAD is

²³³ Gregory Jenkins, chief of advanced concepts, plans and programs, armament product directorate, interviewed by the author 09 October 01.

best delivered directly to the area by aircraft, UCAVs, or missiles. This delivery method avoids wasting the LOCPAD's fuel and increases its loiter time in the search area. One favorable feature of the LOCPAD is that unlike reusable platforms that must return to base before exhausting their fuel, the LOCPAD is expendable and continues searching for targets until all of its fuel is exhausted. Once all of its fuel is consumed, the LOCPAD is programmed to either attack the nearest target of opportunity or self-destruct at altitude.²³⁵

The LOCPAD's ISR suite detects, locates, and identifies targets using several different sensors and processes. To detect targets, the LOCPAD uses IR imaging and passive millimeter wave (PMMW) radar located in its wing's leading edge. Because it uses both IR and radar sensors, the system is capable of detecting targets in adverse weather conditions like rain or light fog.²³⁶ When the system detects a potential target, a flash LADAR located in the munition's nose takes a 3-D picture of the object.²³⁷ After this, the image is either data linked to a ground station where a human operator identifies and confirms the target, giving consent for attack, or the LOCPAD uses its on-board ATR algorithms to decide for itself (see Figure 2, The Preemptive Kill Chain).²³⁸ Because ATR software may not be reliable in all cases, the LOCPAD's ability to use MITL guidance is a big advantage over other purely autonomous weapons like LOCAAS.²³⁹ Nevertheless, LOCPAD does incorporate ATR technology so it can operate

²³⁴ Ben Plenge, AFRL/MN LOCPAD project engineer, interviewed by the author, 19 November 2001.

²³⁵ Jenkins, 3.

²³⁶ Gregory Jenkins interview.

²³⁷ Ibid. While LADAR imaging does not work in all types of weather, it successfully imaged an object obscured by heavy fog at 1.2 km. Using unaided vision, the object was lost at 0.7 km.

²³⁸ Jenkins, 3.

²³⁹ A full discussion of ATR technology limitations is presented in the LOCAAS section of chapter 3.

autonomously in those environments where the risk of fratricide or collateral damage is minimal.

To kill its prey, the LOCPAD employs either sensor-fused weapons (SFWs) or a five-pound blast-fragmentation warhead similar to a combined-effects bomblet.²⁴⁰ The LOCPAD carries two SFWs internally, and because they are better optimized to kill vehicles and armor than the five-pound warhead, SFWs are the preferred method of kill.²⁴¹ To employ SFWs, the LOCPAD flies over the target and ejects a SFW. Once ejected, the SFW spins-up, senses ground elevation, searches for a heat source, and then fires an explosively formed projectile (EFP) into the target at 4,500 feet per second (FPS).²⁴² While complex, SFWs are not new and have been used operationally since 1997 when two B-1B's carrying CBU-97/B were dispatched to Bahrain.²⁴³ After the two SFWs are expended, the five-pound blast-fragmentation warhead can be delivered via a suicide mode where the LOCPAD crashes into the intended target.²⁴⁴ While this mode is an option, selecting a different LOCPAD (with unexpended SFWs) to attack the target will help preserve the overall integrity and effectiveness of the LOCPAD constellation.

To allow control of the LOCPADs, a full duplex data link (4-watt S-band type) is used.²⁴⁵ Since the data link is limited to LOS, however, a "gateway" LOCPAD operating above 5,000 feet AGL is used to transfer the information to other platforms like Global Hawk or Predator, which in turn can relay the information to the LOCPAD's command

²⁴⁰ Combined-effects bomblets are used in CBU-87 cluster bombs to attack soft vehicles and personnel. The bomblets are effective against armor when a sufficient number of bomblets hit the target, normally 8 to 10 bomblets per 1000 square feet will suffice.

²⁴¹ "Smart Munitions: The Next Generation," Public Domain at Yahoo.com, on-line, n.p., Internet, 12 October 2001, available from <http://www.vectorsite.tripod.com/arbomb9.html>.

²⁴² Jenkins, 2.

²⁴³ CBU-97/B is a wide area cluster munition containing multitudes of SFWs; Robert Wall, "The Devastating Impact of Sensor Fuzed Weapons," *Air Force Magazine*, March 1998, 28.

²⁴⁴ Jenkins interview.

module.²⁴⁶ This relay capability is important because one of LOCPAD's strengths is its ability to operate deep inside enemy territory well beyond where standoff airborne sensors can detect emerging targets. As information is received and assessed at the command module, the operator can then shift the entire LOCPAD constellation to a new location, order a specific LOCPAD to attack a specific target, or gather BDA by tasking a LOCPAD to take LADAR imagery of previously attacked targets. The collected imagery allows BDA to occur in real-time and, if necessary, enables the operator to order an immediate restrike. In sum, the data link architecture adds a robust capability to LOCPAD, and it gives the operator the needed flexibility to respond quickly to emerging targets, even when operating deep inside enemy territory.

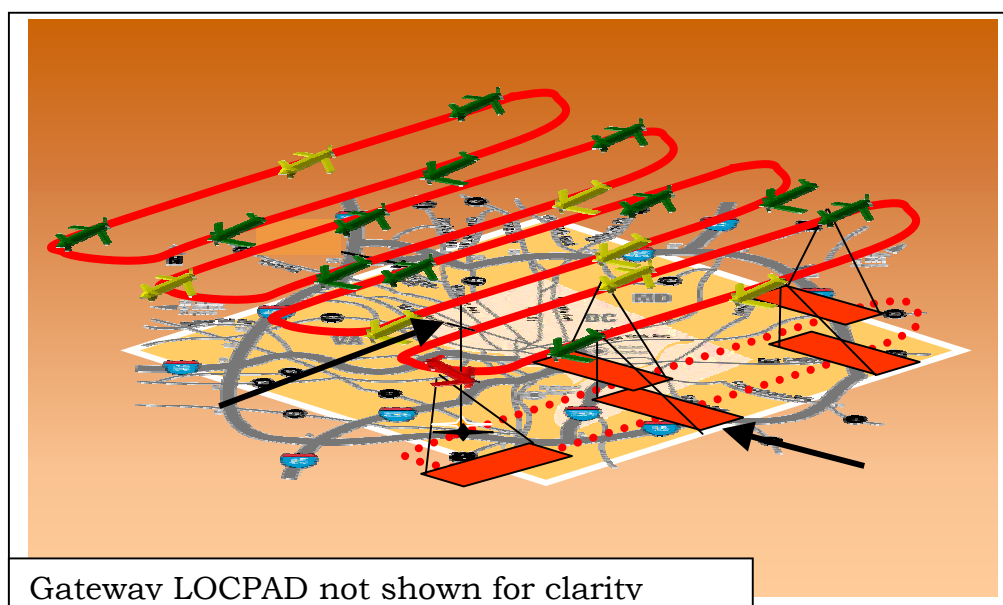
Another area that is enhanced through the use of data link is the LOCPAD's constellation search coverage. Since LOCPADs must search an area continuously to ensure detection of emerging targets, they must communicate with one another and setup an optimized systematic search pattern. One simplified pattern is shown in Figure 4 and illustrates how spacing and deconfliction between the LOCPADs might look. Using a data link for communication, each LOCPAD station keeps and makes corrections to its orbit to optimize the constellation's coverage. For convenience, the corrections occur automatically and do not require any operator input. Since it is envisioned that a plethora of LOCPADs orbiting at low altitudes over enemy territory might be detected and engaged, however, each LOCPAD pattern is periodically changed in both altitude and cross range to reduce predictability and increase survival.²⁴⁷

²⁴⁵ Jenkins, 2.

²⁴⁶ At 1,500 feet AGL, LOS is achieved out to 250 miles provided the terrain is relatively flat. Past this distance, the earth's curvature prevents unobstructed LOS; most likely located in the AOC.

²⁴⁷ Jenkins, 2.

While altering the LOCPAD's flight profile will likely increase survivability, the LOCPAD is still exposed to enemy air defenses. The LOCPAD's optimum altitude is about 1,500 feet AGL, and because flying lower decreases its search area coverage and flying higher degrades its ability to detect and identify targets, the LOCPAD is limited in the amount of altitude it can vary and still be effective.²⁴⁸ For these reasons, the LOCPAD remains in the heart of many enemy threat systems.



Source: USAF Armament Product Directorate
Figure 4. LOCPAD's Search Constellation

While design experts assert that manpads, radar-guided SAMs, and radar-guided AAA cannot successfully engage the LOCPAD because of its extremely small radar cross-section and virtually undetectable heat signature, small arms fire and optically

²⁴⁸ Plenge interview.

aimed AAA may be able to effectively engage the LOCPAD.²⁴⁹ Experience has shown that the key to minimizing losses to small arms fire and optically aimed AAA is to avoid visual detection, and because of this fact, today the USAF normally employs the majority of its strike aircraft at altitudes above 15,000 feet.²⁵⁰ While this altitude works well for aircraft, testing is yet to be done to determine if an adversary can visually detect a small LOCPAD loitering at 1,500 feet AGL. Although somewhat imprecise, a comparison can be made on a basis of scale. Since manned fighter aircraft operating at or above 15,000 feet normally remain visually undetected, a miniature munition loitering over the enemy at 1,500 feet undetected would need to be about one-tenth the size.²⁵¹ Using the dimensions of an F-16 for comparison, the munition would need a wingspan of less than 3.3 feet and overall length of less than 5 feet to avoid detection. Engineers currently designing the LOCPAD confirm that it will likely measure no more than 48 inches long with a wingspan under 3 feet.²⁵²

One option that may help further prevent the enemy from visually detecting LOCPAD is to use camouflage paint so the munition blends into the sky. With less contrast, LOCPAD would be more difficult to see and may even prevent an enemy using optical devices with magnification (i.e., binoculars) from detecting it. Because no one camouflage pattern works in all environments, however, changing weather conditions will be a concern and most likely negate the camouflage's effectiveness. For example, cloud and haze backgrounds are ideal for visually detecting overhead flying objects

²⁴⁹ Optically aimed AAA normally uses a magnified aiming device like a wide-area telescope to detect and track a target. Manpads are shoulder-launched SAMs that lock-on and track the heat emitting from an object.

²⁵⁰ Jumper, address to the AFA's 17th annual air warfare symposium.

²⁵¹ Another consideration is the LOCPAD's acoustic footprint. If an enemy can hear LOCPAD, then they might spend more time trying to engage it.

²⁵² Plenge interview.

(regardless of camouflage) because they appear as dark objects moving against a light background. Thus, while painting LOCPADs will help them avoid enemy detection, the tactic will not work in all environments, possibly causing LOCPADs to face enemy fire.

Another concern is the LOCPAD's ability to survive enemy barrage AAA fire. Barrage AAA fire is designed to fill a volume of space or area rather than aimed specifically at a given target.²⁵³ Because the technique is extremely inefficient (i.e., shooting enough projectiles to fill up a large volume of airspace), fire is usually not initiated until attack is either impending or already underway. This reservation helps ensure that aircraft are at least overhead before expending ammunition. In addition, since filling up large volumes of airspace is difficult to achieve by shooting individual bullets, shells are used that explode at predetermined altitudes and send bits of shrapnel (called flak) blitzing through the air. In effect, each exploding shell covers a much larger volume of airspace than an individual bullet, resulting in a more effective and efficient defensive system. As evidenced in WWII, this type of barrage fire has both damaged and fatally wounded attacking aircraft. In regard to LOCPAD, however, it appears that using barrage fire with explosive shells may not be a likely option.

Since the LOCPAD flies at roughly 1,500 feet AGL, shells would need to detonate at about the same altitude. If this were to happen, however, not only would the LOCPAD be subject to the blast, but also ground troops (to include AAA operators) located in the vicinity. In fact, the smallest Soviet AAA round that incorporates a self-destruct option is 37mm, and its minimum detonation altitude is 3,700 meters, or about

²⁵³ Joint Publication 1-02, 47.

11,000 feet, well above where LOCPAD operates.²⁵⁴ Larger shells offering more blast only serve to compound the problem. For this reason, it is unlikely that LOCPAD will face exploding shells, and if they are not used, then it will be difficult at best to achieve the required concentration of AAA fire to effectively engage a LOCPAD. So while the enemy may score an occasional "golden BB" and shoot down a LOCPAD without explosive shells, random firing with unitary bullets will probably not prove all that effective. For those cases where the enemy does successfully engage LOCPAD, however, replenishing munitions will be required to replace attrition and keep the constellation effective.

The number of LOCPADs required to hold an area at risk depends on the size of the area, the target's maximum travel speed, the target's engagement speed, the LOCPAD's rate of coverage, and the rate of attrition. As with the LOCAAS, the number of LOCPADs needed to cover an area varies with the square of its radius. The target's speed is a concern because enough LOCPADs must cover the area fast enough so that if a target emerges, it cannot escape the area before a LOCPAD detects it. Target engagement speed is also important because LOCPAD must detect an emerging target before it can setup and engage friendly forces. LOCPAD's rate of coverage varies with its speed and altitude, and remains relatively constant. The last factor, attrition, will need to be factored into the equation once further study is accomplished and accurate data is obtained. Taking into account these factors, tentative calculations show that a 14-km x 14-km area (roughly equivalent to 70-sq. mi.) requires thirty-two LOCPADs to keep a

²⁵⁴ Federation of American Scientists, "M1939, 37 mm AAA," on-line, n.p., Internet, 28 April 2002, available from <http://www.fas.org/man/dod-101/sys/land/row/m1939.htm>.

60-kph target (like a SCUD TEL) from escaping detection for a twelve-hour period.²⁵⁵

With so many LOCPADs required to hold even a small area at risk, cost soon becomes a big concern.

Originally, each LOCPAD was estimated to cost about \$33,000, or roughly equivalent to a LOCAAS. But, with LOCPADs advanced sensor suite and data link communications, the experts now predict each LOCPAD will cost about \$100,000, which equates to about six JDAMs.²⁵⁶ Furthermore, if JASSM, conventional cruise missiles, or hypersonic missiles deliver the munition instead of aircraft or UCAVs, the price of employment increases dramatically. So while LOCPAD offers increased capability over other types of munitions, unless it is employed by either manned or unmanned aircraft, it will not likely prove cost effective for prolonged employment scenarios or where multitudes of LOCPADs are needed to cover large target areas.

Fortunately, the USAF is developing several platforms that will be able to employ LOCPADs. The F-22 is capable of carrying at least nine LOCPADs internally along with a complement of air-to-air missiles.²⁵⁷ The JSF will also have the capability to deliver LOCPAD, but current data does not state how many. With two 168-inch weapon bays, the stealthy X-45 UCAV will also be able to carry LOCPADs and, because of its ability to operate autonomously, may be the perfect choice to deliver the munitions to their areas of operation. In the end, evidence suggests that delivering LOCPADs with manned aircraft or UCAVs may not be a concern.

²⁵⁵ Jenkins, 3.

²⁵⁶ Plenge interview.

Summary

The preemptive approach offers an alternative approach to the traditional reactionary kill chain and relies on one's ability to successfully predict enemy target locations and then use integrated weapon platforms to continuously survey the area for emerging targets. By using different intelligence techniques such as area delimitation, PBA, and surveillance, it appears that successful target prediction may be possible in future conflicts. But, since it will not likely be perfect, future commanders will need to assess the level of risk acceptable verses the cost of preemptive weapon employment.

While manned aircraft have been used successfully in this role in the past, notably in benign threat environments or where commanders have had a preponderance of assets, they are usually not well suited to perform the role of an integrated weapons platform in high threat areas or with limited assets because of the incurred costs. Predator offers a reasonably cheap solution but is hardly effective due to Hellfire limitations and lack of carriage capacity. Although Gator offers the advantage of persistence, its effectiveness is marginal because targets disperse early and then travel on unprepared surfaces, thus eliminating choke points that would normally serve to funnel them into minefields. Also, the Ottawa Mine Ban Treaty creates political pressure that will likely negate, or at least limit, its future use. LOCPAD offers a promising alternative to a commander because of its long-loiter capability, MITL guidance, and relatively cheap cost (provided either manned or unmanned aircraft deliver it). Future study will be required to fully analyze the LOCPAD's survivability, but it appears possible that it will meet needed requirements. Now having investigated all of the possible future capabilities for 2010 in

²⁵⁷ Jenkins, 2.

chapters 3 & 4, chapter 5 analyzes the capabilities, highlights shortfalls, and determines the best future course of action.

Chapter 5

Results & Conclusions

Having investigated the different methods and techniques that can be used for time critical targeting in the future, this chapter condenses and analyzes the evidence and recommends the best course of action. The chapter is separated into two sections. Section one determines if there is a future need for persistent area dominance munitions based on future ISR capabilities and weapons, offering several conclusions based thereon. Section two capitalizes on section one's results and investigates the feasibility of persistent area dominance munitions in meeting any shortfalls. The chapter concludes with a summary of its findings.

Section 1 - Is there a need?

As was presented in Chapters 2 and 3, the USAF is aggressively pursuing ways to reactively engage TCTs through the development of sophisticated ISR platforms that can find and then cue strike platforms to emerging targets. Two problems associated with this approach are: (1) achieving continuous ISR coverage over areas of enemy territory with enough fidelity to accurately detect, locate, and identify emerging targets, and (2) possessing the capability to quickly kill the target before it hides. Based on all the evidence currently available, it is not likely that the USAF will have solved these problems by 2010.

The first problem will continue to plague the process because the space-based radar will not be operational until about 2020, and until it is, ISR sensors will not be capable of providing persistent coverage deep inside enemy territory (beyond where standoff sensors can look - typically 100-150 miles behind enemy lines) where many

TCTs will likely exist.²⁵⁸ Even with UAVs like Predator and Global Hawk that have the capability to loiter deep beyond the enemy's borders, evidence shows that their vulnerability to enemy air and surface threats will either limit employment opportunities or necessitate manned assets to support their operations. Manned aircraft, however, are poorly utilized in this role because of efficiency constraints. For these reasons, high threat areas beyond the range where standoff ISR sensors can search present a unique challenge, one that UAVs are not likely to solve. In the end, because little or no continuous ISR coverage is available in these areas to cue strike platforms to emerging TCTs, the reactionary method of detecting and then striking falls flat.

The result is if the USAF remains fully reliant on the reactionary approach, little or no capability to engage TCTs deep inside enemy territory will be likely, even if strike platforms are available. If for this reason alone, the USAF needs to seriously consider a way to bridge this gap. The predictive approach utilizing persistent area dominance munitions might be an attractive option, at least until the space-based radar comes online about 2020. Furthermore, the acquisition of persistent munitions like LOCPAD may serve to increase a much needed ISR capability while also acting as a safety net in case future budgetary constraints delay either space-based radar operations or projected ISR upgrades.

The second problem is devising a weapon with the ability to strike an emerging target before it hides. Since evidence does suggest that future ISR platforms will be capable of finding and identifying emerging targets within their search areas, reactionary strike platforms that quickly and effectively engage emerging targets are needed. Based

²⁵⁸Michael R. Gordon and General Bernard E. Trainor, *The General's War* (NY.: Little, Brown and Company, 1995), 247. In the Gulf war, Iraqi SCUDs moved deep behind enemy lines once aware of their

on the future weapons investigated in chapter 3, however, it appears that meeting this requirement will be difficult at best, especially against TCTs in either high threat areas or deep inside enemy territory.

All the systems investigated (AMSTE, UCAVs, hypersonic missiles, and LOCAAS) have significant drawbacks that hinder their ability to quickly engage emerging targets. AMSTE suffers from a variety of setbacks, which include line-of-sight (LOS) obstructions to distant targets (or close targets located behind mountains), the necessity for multiple radars to track a single target, and the need for a delivery platform to encroach the target area. Due to the inadequacy of using UAVs in high threat areas, the LOS problem will not likely be resolved until the space-based radar is operational, and until then, LOS obstructions will likely remain a boundary that prevents AMSTE from engaging TCTs in deep or hostile areas. In addition, because the number of ISR target tracking radars in 2010 will be limited, utilizing the few available radars for target engagement hinders the entire ISR effort. Lastly, since AMSTE requires an aircraft or UCAV to fly relatively close to a target to deliver a weapon, evidence suggests that AMSTE does not deliver significant advantages over current capabilities. In the end, while AMSTE's projected capabilities are somewhat encouraging, they will not come to fruition until beyond 2010.

The UCAV also has its share of problems. Although billed by the USAF as the answer to dull, dangerous, and dirty missions, evidence suggests that the UCAV will not only falter in meeting these claims, but also it will also fail to meet the single-digit TCT timeline for two fundamental reasons: range limitations and responsiveness. With a 650-mile range and no air refueling capability, the UCAV is only capable of striking seventy

vulnerability to detection by coalition standoff ISR platforms.

percent of the targets located within enemy territory.²⁵⁹ So while the stealthy UCAV enjoys autonomy of operation against enemy threat systems, it hardly matters if it cannot reach emerging targets. Also, since the UCAV's limited range translates to a limited loiter capability, it cannot orbit for long periods while waiting for TCTs to emerge in forward areas. While one answer may be to cycle UCAVs routinely in and out of orbits, these types of operations are hardly efficient and have traditionally been avoided. These two limitations, in conjunction with the UCAV's moderate speed that further restricts its ability to respond to emerging targets, results in a strike platform that has difficulty accomplishing not only the dull, dangerous, and dirty missions, but also in meeting the required timelines for engaging TCTs. For the above reasons, evidence suggests that the UCAV will offer little help in solving the TCT problem.

The next system is hypersonic vehicles, and while they solve the range, survivability, and timeliness problems incurred with AMSTE and UCAVs, they have other limitations that plague their development and use. The first problem involves finding a way to fit explosive munitions into a slender hypersonic missile that heats up to extremely high temperatures. After this feat, one must then find a way to expel munitions like LOCAAS without causing undue harm. In essence, this means slowing a Mach 5 to 8 missile down to subsonic speed before ejecting the munitions. Since both of these problems result from the hypersonic missile's inability to track moving targets while in flight, necessitating the use of an AAL munition (like LOCAAS), both problems could be solved at once by using a system like AMSTE. As discussed earlier, however, AMSTE will not be ready until after 2010. Another overriding problem of hypersonic missiles is their high cost. Considering that only two LOCAAS type munitions will

²⁵⁹ See chapter 3, UCAV for details.

likely fit into a hypersonic missile, and that a minimum of 4-10 LOCAAS are required to search a target area, many missiles will be required to deliver the munitions.²⁶⁰ At about \$200,000 each, cost will likely limit the number of missiles acquired and, therefore, their potential for use.

The last system for discussion is the LOCAAS, and while it holds great promise, it too will not likely solve the TCT problem because it lacks a reliable target recognition capability and a cost-effective vehicle that can quickly deliver it to deep or hostile areas. ATR algorithms used by LOCAAS in 2010 will not likely be accurate enough to ensure military commanders that collateral damage and fratricide will not occur, and because of this limitation, commanders will likely shy away from employing LOCAAS. This does not imply all cases of conflict because in large wars where the stakes are high, politics may allow commanders to accept increased risk. Unfortunately, recent wars have asserted the need to avoid collateral damage and fratricide, and, according to leading scholars and military commanders, the requirement will likely persist in the future. Furthermore, since LOCAAS's ATR program only recognizes those targets preprogrammed into its memory, the enemy will likely take advantage of this limitation and slightly alter the shape of their vehicles (with a piece of plywood, etc.), causing the LOCAAS to misidentify a hostile vehicle as an unknown.²⁶¹ Without MITL guidance to further analyze and clarify the situation, LOCAAS will likely be ineffective.

The second problem with LOCAAS is achieving a timely response because of delivery delays. As chapter 3 suggested, LOCAAS is best delivered by either manned

²⁶⁰ Based on 15-minute time delay with a target speed ranging from 20-35 km/hr.

²⁶¹ Daniel L. Byman, Eric Larson, and Matthew C. Waxman, *Air Power as a Coercive Instrument*, (Washington, D.C.: RAND, 1999), 131. The coercive paradox asserts that the more formidable air power or any other instrument of coercion, the more likely adversaries are to be prepared for it.

aircraft or UCAVs to keep costs minimized. But, as was discussed earlier, UCAVs lack range, persistence, and responsiveness, and while manned aircraft overcome the range limitation, they suffer from the traditional problem of needing support assets to accompany them to the target. In the end, it appears that delivering LOCAAS quickly to deep or hostile areas with aircraft and UCAVs is a limitation not easily solved.

The above findings strongly suggest that none of the reactionary weapons currently being pursued by the USAF will likely meet the needed requirements to quickly and effectively strike TCTs, especially those residing deep inside enemy territory or in high threat areas. In situations where the enemy's IADS are negated, history has clearly demonstrated that while UAVs and legacy strike platforms can operate freely and contribute to the effort, they are only marginally effective in such roles. This is why the USAF is pursuing so many different types of systems to alleviate the problem. The end result in 2010, however, is that if the USAF continues to solely pursue reactionary weapons, it is likely that the USAF will still operate under the old paradigm that it desperately seeks to correct. Here, LOCPADs may provide the means to fill this gap while there is still time to perfect the technology.

It is important to note, however, that just because ISR and reactionary weapons will not likely be adequate in 2010 to engage all TCTs in single-digit minutes, it does not imply that they should not be pursued. The crux of the matter is that the reactionary approach is inherently efficient from a weapons perspective because they are not employed until a target is confirmed, and as a result, fewer weapons are used per target. The approach's inefficiency results from tasking delivery platforms to loiter while waiting for TCTs to emerge, and then in many cases still not being able to respond fast enough.

If hypersonic vehicles and AMSTE can be perfected and incorporated in the post-2010 era, however, standoff ISR platforms could also serve as hypersonic missile delivery platforms, greatly enhancing efficiency and reaction time in one fell swoop. So while the reactionary approach will still likely be broken in 2010, long-term technological advancements and ISR upgrades will likely render the approach cheap, effective, and efficient.

Section 2 - Can persistent area dominance weapons alleviate the shortfalls?

This section investigates whether or not persistent area dominance weapons (like the LOCPAD) can help solve the problems presented in section one. It is important to remember that the question is not whether persistent area dominance weapons can destroy ninety percent or only fifty percent of time-critical targets, but rather whether preemptive systems can enhance future capabilities at a reasonable cost. To answer the question and make a recommendation, two areas are investigated: (1) predictive capability, and (2) effectiveness, cost, and ease of integration. After analyzing these areas, results are presented that recommend whether or not the USAF should pursue the approach.

Predictive capability

As was discussed in Chapter 4, the key enabler to the preemptive approach is a robust intelligence network that allows one to predict when and where to use preemptive weapons. In fact, if one can get this part of the equation correct, killing TCTs in single-digit minutes is easily accomplished provided enough munitions are orbiting over the

area. Evidence suggests that while the art of prediction will be easier in 2010, it will not be perfected and will still require a commander to calculate the costs and benefits of employing preemptive weapons. Furthermore, because the limitation of ISR continuously observing the enemy deep inside his territorial boundaries will continue in 2010, obtaining the necessary levels of intelligence to employ preemptive munitions in these areas will be difficult.

One method that may help alleviate the difficulty is to use a few LOCPADs in a surveillance role by orbiting them over an area to gain information. By using only a few LOCPADs at a time, costs are kept low. If the collected information then warrants the use of an entire LOCPAD constellation, a commander can easily up the ante and fully invest in the effort. While this technique still requires PBA and analysis to determine where to initially place the surveillance LOCPADs, it does prevent using multitudes of munitions without first investigating the situation. In the end, LOCPADs can increase ISR collection, help increase the odds of successful prediction, and may propagate further LOCPAD employment if warranted.

Effectiveness, cost, and ease of integration

This section discusses some possible problems with LOCPAD, determines their importance, and decides whether they can be overcome.²⁶² Specifically, it addresses LOCPAD's target recognition and identification capabilities, delivery methods, and cost. Like LOCAAS, LOCPAD uses LADAR and ATR technology as a basis for target identification, and some fear that it will not discriminate real targets from others. As addressed in chapter 4, however, while LOCPAD does have an ATR capability, its primary method of identifying targets is by utilizing MITL guidance where a human

operator looks at a suspected target and makes a determination. So unlike LOCAAS where the ATR process is entirely automated by computer, MITL guidance helps prevent collateral damage and fratricide by inserting a human operator who can decide whether or not to attack targets on a case-by-case basis. The associated accountability allows commanders to employ LOCPADs with less fear of political disaster. In addition, small structural changes to targets are less likely to fool a trained human operator than a computer "match-making" ATR algorithm that cannot reason and make selective judgements. For all these reasons, evidence shows that commanders have little reason to fear that LOCPAD will attack an improper target.

LOCPAD delivery is also a concern because, like the LOCAAS, it also is best delivered by manned aircraft and UCAVs to keep costs minimized. The main difference between the two delivery requirements, however, is that while LOCAAS requires a fast response time, LOCPAD does not. LOCPADs are preemptive munitions that have a long loiter capability of about twelve hours, and, because of this, LOCPAD constellations only need servicing twice a day. Since manned aircraft already successfully operate deep within enemy territory by forming strike packages, LOCPAD deliveries can be tasked on the daily air tasking order (ATO) and incorporated into preplanned strike operations. The end result is that while some inefficiency is brought into the system because delivery aircraft are employing weapons that may not find a target, it is much more efficient than tasking strike and support aircraft to loiter continuously while waiting for an emerging TCT, even if dump targets are utilized.²⁶³ Once the constellations are serviced, the strike

²⁶² Since Gator mine did not fulfill the needed requirements, it will not be discussed further.

²⁶³ A dump target is normally a low priority target located outside known enemy threats that can be attacked if (in this case) a TCT does not emerge. In essence, the commander is able to get some use out of the sortie, but very little since the destruction of dump targets typically achieves little effect.

assets operate freely against other target sets as usual. In essence, the vast amount of the preemptive approach's inefficiency results from the numbers of LOCPADs used without guarantee of success, not by tying up more valuable strike and support assets. The net result is that LOCPAD integrates easily into strike operations, can be employed in deep enemy areas, and offers increased efficiency of delivery assets in comparison to the reactionary approach. One concern that does hinder LOCPAD employment, however, is cost.

As previously stated, the overriding inefficiency occurs when LOCPADs are used in areas where TCTs do not exist. With a price tag of \$100,000 each and requiring at least thirty-two LOCPADs to cover a 70-sq. mi. area for a twelve-hour period, LOCPADs are not a cheap option. In cases where TCTs are weapons of mass destruction or threaten coalition cohesiveness, such costs might not only be acceptable, but a bargain. In other cases where the threat is less, LOCPAD's cost may not be justified. Perhaps in these situations, LOCPADs can be used in an ISR role as suggested earlier. In the end, when considering the high cost of operating manned platforms that require highly trained aircrew, expensive aircraft, and a robust support network, the LOCPAD is a cheap option in relative terms. Nevertheless, a cost-benefit calculus is needed before employing multitudes of LOCPADs.

Conclusions

Based on the above analysis, a few conclusions are formulated. First, the road the USAF is currently travelling contains large potholes that need filling. The potholes primarily stem from a lack of ISR and weapons capabilities that fail to quickly engage TCTs in deep or hostile areas. Second, LOCPAD is a viable option that can fill these

potholes by integrating easily into today's strike operations, accessing deep target areas, and increasing delivery vehicle efficiency. Third, a robust intelligence network is needed to enable the preemptive method, and LOCPAD may help fulfill this requirement by increasing ISR collection. Fourth, because LOCPADs quickly become expensive when used en masse, commanders will need to prioritize where and when to use LOCPADs based on a cost-benefit calculus. Fifth, LOCPADs will complement reactionary weapons after 2010. By employing both reactionary and preemptive methods in the future, predictive intelligence can better align reactionary forces, and reactionary ISR platforms can move LOCPAD constellations to target rich areas as they appear. The resulting synergy will enhance the overall efficiency of the effort. Lastly, the USAF should continue pursuing the reactionary approach since it promises a cheap, effective, and efficient solution to engaging TCTs once the technology is perfected. As the approach becomes feasible, LOCPAD force structure will need reassessing.

BOTTOM LINE: The USAF should further investigate and pursue persistent area dominance munitions as an answer to the TCT problem. The LOCPAD is a munition already under study by AFRL and would most likely be easy to develop, incorporate, and operationalize into USAF doctrine. Further study should be accomplished to determine how many munitions are required based on future projections of conflict.

Glossary

AAL	Acquire after launch
AAR	Air to air refueling
AARMD	Affordable rapid response missile demonstrator
ABCCC	Airborne battlefield command and control center
ABL	Acquire before launch
AOI	Area of interest
AP	Anti-personnel
AT	Anti-tank
ACC	Air combat command
AC2ISRC	Air command and control, intelligence, surveillance, and reconnaissance center
AFRL	Air Force Research Laboratory
AGL	Above ground level
ALSA	Air, land, & sea application center
AMSTE	Affordable moving surface target engagement
AOC	Air operations center
ASARS	Advanced synthetic aperture radar system
ATD	Advanced technological demonstrator
ATR	Automatic target recognition
BDA	Battle damage assessment
BVR	Beyond visual range

CALCM	Conventional air-launched cruise missile
CAP	Combat air patrol
CFAR	Constant false alarm rate
COG	Center of gravity
COI	Contact of interest
CONOPS	Concept of operations
C2	Command and control
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DSP	Defense support program
EA	Electronic attack
EO	Electro-optical
ESAR	Enhanced synthetic aperture radar
FAC	Forward air controller
FCS	Future combat systems
FLOT	Forward line of troops
FolPen	Foliage penetrating radar
FOV	Field of view
FPS	Feet per second
GP	General purpose
GPS	Global positioning system
GWAPS	Gulf War Air Power Survey
HARM	High-speed anti-radiation missile

HF	High frequency
HiSSS	High speed strike system
HRR	High range resolution
I-REMBASS	Improved remote battlefield acoustic and seismic system
ISAR	Inverse synthetic aperture radar
ISC	Infiltration surveillance center
ISR	Intelligence, surveillance, and reconnaissance
IUGS	Internetted unattended ground sensor
JASSM	Joint air-to-surface standoff missile
JDAM	Joint direct attack munition
JFACC	Joint forces air component commander
JFC	Joint forces commander
JSOW	Joint standoff weapon
LADAR	Light detection and ranging
LOCAAS	Low cost autonomous attack system
LOCPAD	Low cost persistent area dominance munition
LOS	Line-of-sight
MAP	Mission area plan
MCE	Mission control element
MC2C	Multi-command and control constellation
MITL	Man-in-the-loop
MNS	Mission needs statement
MP-CDL	Multi-platform common data link

MP-RTIP	Multi-platform radar technology insertion program
MRLS	Multiple rocket launch system
M3T	Multi-theater target tracking capability
MTI	Moving target indicator
NBC	Nuclear, biological, chemical
NFOV	Narrow field of view
NVG	Night vision goggles
OCA	Offensive counter-air
OEF	Operation Enduring Freedom
OPNAV	Office of the Chief of Naval Operations
PBA	Predictive battlespace awareness
PGM	Precision-guided munition
PMMW	Passive millimeter wave radar
P3I	Pre-planned product improvement
REMBASS	Remote battlefield acoustic and seismic system
ROE	Rules of engagement
SAM	Surface-to-air missile
SAR	Synthetic aperture radar
SBR	Space-based radar
SDB	Small diameter bomb
SDD	System design and development
SEAD	Suppression of enemy air defenses
SFW	Sensor-fused weapon

SIGINT	Signals intelligence
SPIRITT	Spectral infrared imaging transition test-bed
TCT	Time-critical target
TEL	Transporter, erector, launcher
TGP	Targeting pod
TLE	Target location error
TMD	Tactical munitions Dispenser
UWB	Ultra wide band
UAV	Unmanned aerial vehicle
UCAV	Unmanned combat aerial vehicle
US	United States
USAF	United States Air Force
VHF	Very high frequency
WAG	Weapons attack guide
WFOV	Wide field of view

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